UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 894

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. PROFESSIONAL PAPER October 18, 1920

MANUAL OF DESIGN AND INSTALLATION OF FOREST SERVICE WATER SPRAY DRY KILN

By

L. V. TEESDALE, Engineer in Forest Products

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

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CONTENTS.

THE WATER SPRAY KILN.

The best thing that can be said of any dry kiln is that when it is run by a properly informed operator the temperature, humidity, and circulation are constant and uniform. In an endeavor to produce a kiln in which each of these could be regulated independently of the others, the Forest Products Laboratory designed and developed the "Forest Service Humidity Regulated Water Spray Kiln,"[1] described in this bulletin. The principle of forced circulation and humidity control by means of sprays of water was the basis of the first patent taken out in 1912 and is the main feature of the present kiln. This dry kiln is well adapted to commercial use in the kiln drying of refractory hardwoods of large dimensions and of green lumber of all kinds, and has attracted attention wherever commercial practice has been forced to realize that drying equipment incapable of close operation will not dry green lumber economically.

Experience has shown that the details of good design and workmanship are often disregarded, with the result that the kiln fails to function as intended. By adhering to the principles herein set forth any competent engineer should be able to design or construct an installation of the size suited to the peculiar needs of a given plant.

[1] For information regarding method of operation, see Forest Products Laboratory report "Notes on the Operation of the Forest Service Water Spray Dry Kiln and Theoretical Considerations of Heat Relations," by H. D. Tiemann.

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The drawings illustrate the principles and the typical forms of construction. The three typical cross-sections of the kiln have been drawn to show some of the possible and allowable variations. Factors influencing such variables are indicated in the text. Thus the drawings may be altered to fit individual requirements and local conditions.

THE KILN.

The kiln proper consists of a drying chamber approximately 11 feet high, 12 to 16 feet wide, and of indefinite length, usually from 20 to 100 feet. The lumber is piled in the kiln lengthwise (with or without kiln trucks) and on either side of a central open space or passageway extending the length of the kiln. This central space, as well as the space between the piles and either side wall, is usually from 1½ to 2 feet in width.

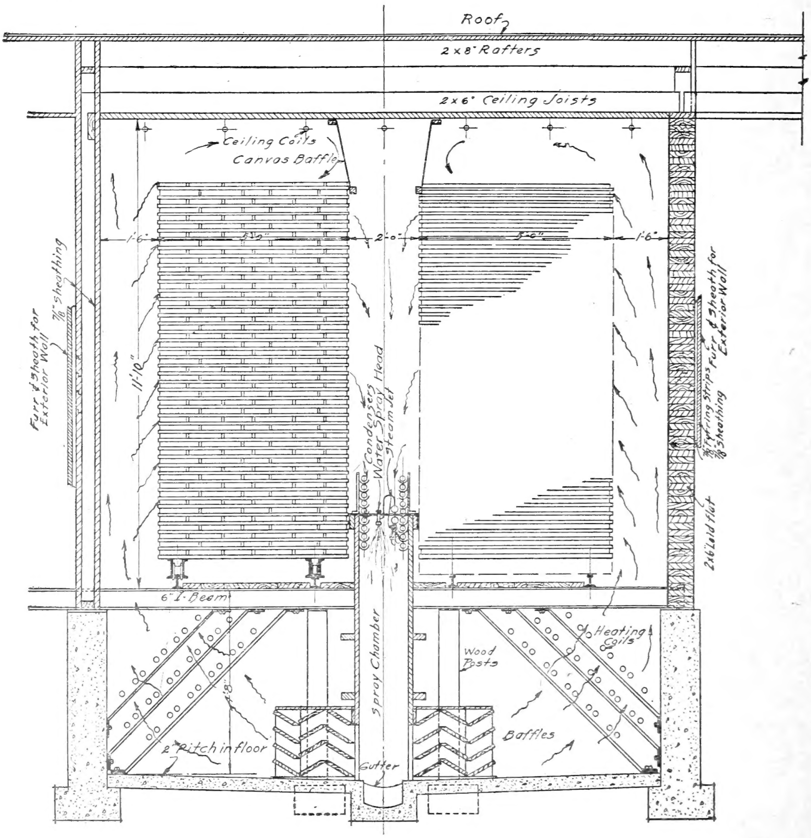

FIG. 1.—Typical cross section of kiln with center-spray chamber. Studs and sheathing, crib construction, wood roof, wood spray chamber, wood posts.

Between the floor of the drying chamber and the bottom of the kiln proper there is a space about 4½ feet high in which heating coils are situated to provide the necessary heat for the drying chamber.

Where high humidities are used, a small heating coil is usually necessary above the lumber to prevent condensation of moisture on the cold ceiling of the drying chamber.

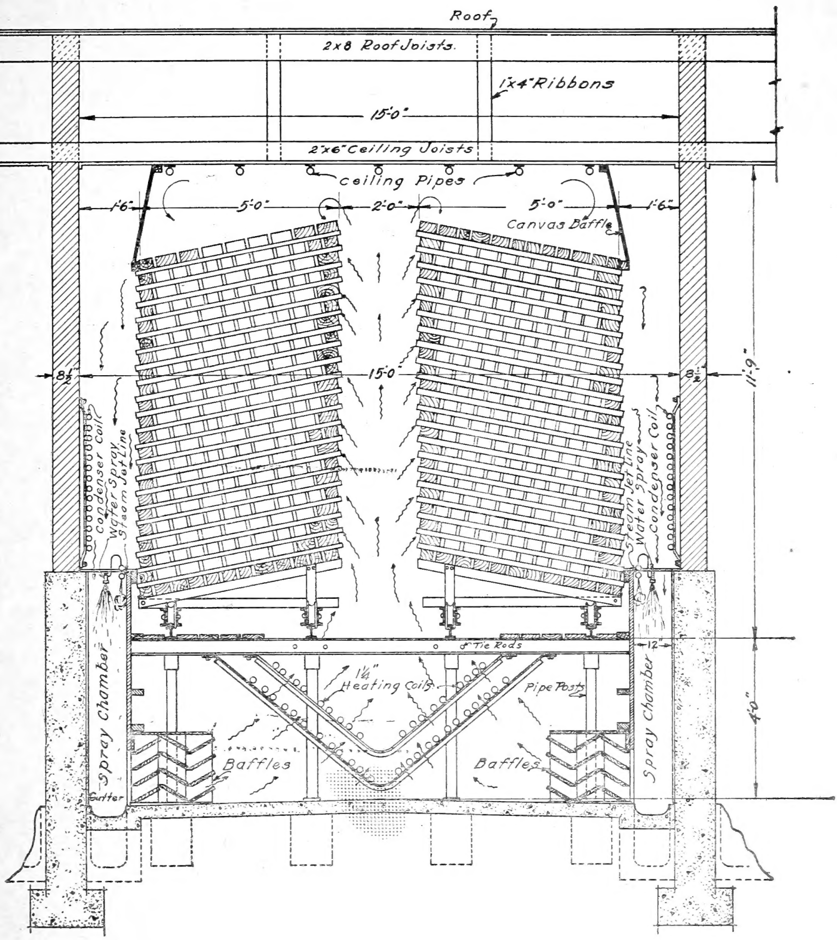

FIG. 2.—Typical cross section. Brick walls, wood spray chamber, wood roof, and slant piling.

At either side of the drying chamber (fig. 2) or along the center thereof (fig. 1) a spray chamber from 12 to 15 inches wide is provided the full length of the kiln. Each spray chamber extends from a point about 18 inches above the floor of the drying chamber to the bottom of the kiln proper. Spray heads are spaced at regular intervals along the top of the spray chamber to deliver cone-shaped sprays of water down the chamber. The water from the sprays drains from the spray chamber to a suitable well. The air current resulting from the action of the water sprays passes out sidewise from the spray chamber at the bottom of the kiln proper. The air as it leaves

the spray chamber is passed through baffle plates, which remove any mist or drops of water but leave the air saturated with moisture. The purpose of the sprays is to induce circulation throughout the kiln by forcing the air down the chambers, to condense the moisture evaporated from the lumber, and to regulate the humidity by controlling the temperature of the air leaving the spray chamber.

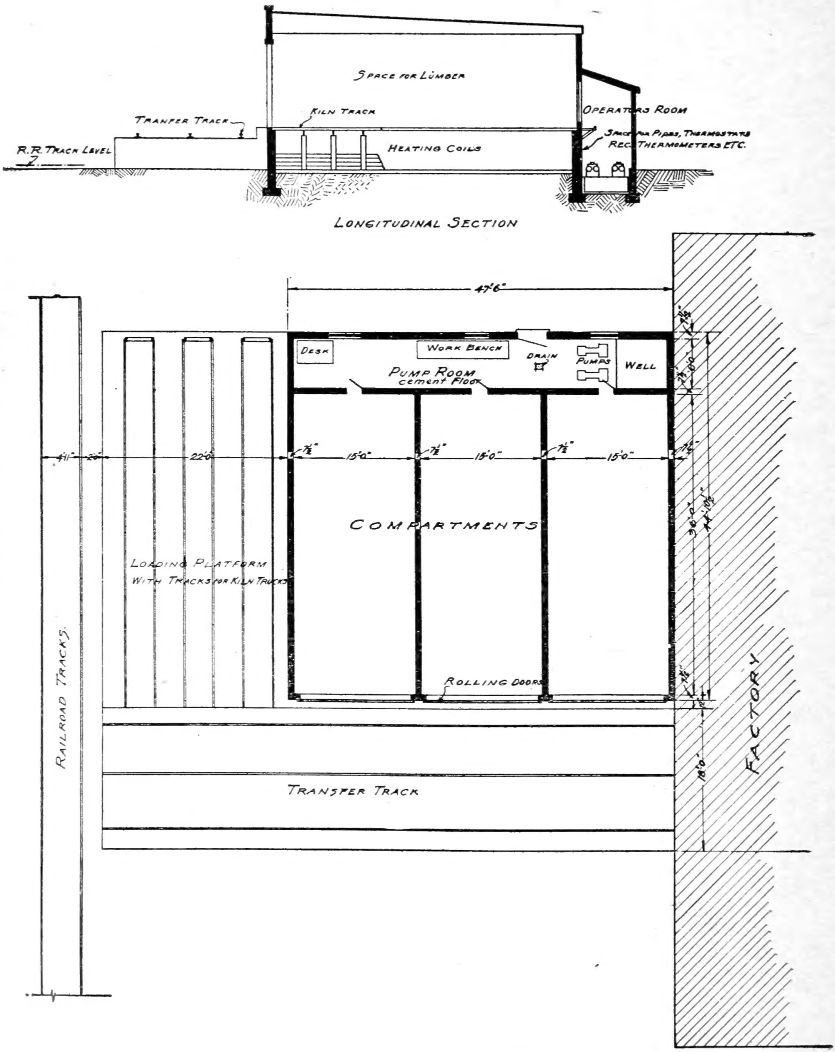

FIG. 3.—Battery of three kilns.

A steam spray or jet line at the top of each spray chamber and extending the full length of the drying compartment admits saturated steam into the kiln when required for "steaming" the lumber.

Condenser coils may be provided on either side of the kiln above the spray chambers, or in the center of the kiln if the kiln is arranged

with center spray chamber, to take the place of the water sprays during the final stage of the drying period under conditions where the use of the coils is considered advisable or economical.

Pumping equipment is provided to recirculate the used water which drains from the spray chambers and to supply cold water (and in some instances, hot water) to the water mixing valve, and from there to the sprays.

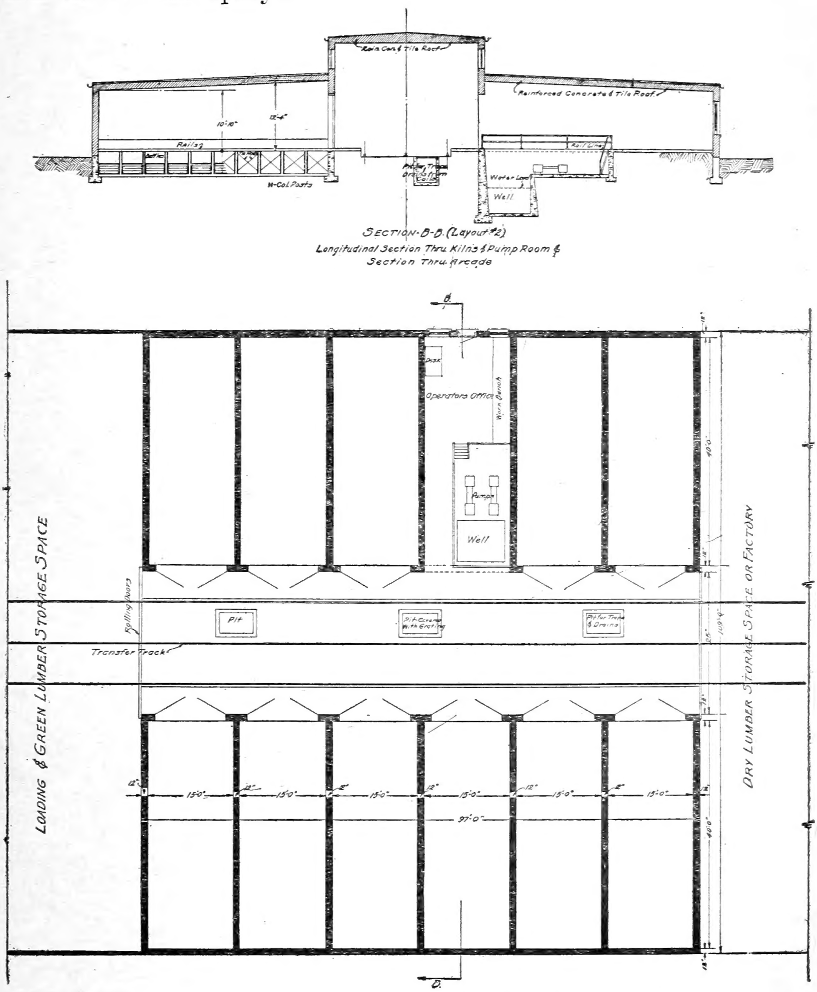

FIG. 4.—Battery of 11 kilns with covered arcade and transfer track.

SELECTION OF KILN SITE.

Efficiency in handling stock depends primarily upon the location of the kilns in relation to the incoming green lumber from the mill and the disposal of the lumber to the shops or otherwise after leaving the kilns. Figures 3 and 4 show typical arrangements of kilns in batteries, and may be readily altered to suit any ordinary requirements.

The pump room should be centrally located in regard to kilns and boiler room, or steam supply.

Access to fresh water and suitable drainage for waste water have a bearing on the location and established grade of the kiln rails.

KILN CAPACITY.

To estimate the capacity in board feet of a kiln of any given size, multiply the following factors:

Thickness of stock in inches.
Number of rows in height.
Width of pile in feet (minus allowance for openings between boards).
Average length of lumber in feet.
Number of trucks or piles in kiln.

Or the following:

Height of pile in inches, less aggregate thickness of stickers in inches.
Width of pile in feet (minus allowance for openings between boards).
Average length in feet.
Number of trucks or piles in kiln.

In determining the kiln capacity required to maintain a given periodic output, a great deal depends on the drying period. Consideration, therefore, must be given to the following items:

Kind of stock to be dried.
Thickness of stock.
Moisture content of stock at time of loading.
Moisture content to which stock is to be dried.
Use to which dried stock is to be put—whether a rapid or slow drying schedule is to be preferred from the standpoint of mechanical properties of the wood.

Where large quantities of lumber of one thickness and species are to be dried, long kilns of large capacity are an economy; where a variety of sizes or species in smaller quantities are to be dried a number of smaller kilns is advisable.

The number of kilns of a given size necessary to maintain a given daily output is determined by the following formula:

$$\text{Desired daily output from kilns} \div \frac{\text{Estimated capacity of 1 kiln unit in board feet}}{\text{Estimated number of days in drying period}} = \text{Number of kilns.}$$

DRYING PERIOD.

Table 1 is intended to give an idea of the approximate time required to dry plain-sawed 1-inch green and partially air-dry stock to 6 per cent moisture content, according to mild drying schedules, which will produce material of the highest quality and equal in strength properties to air-seasoned stock. For stock over 1 inch thick and not over 3 inches thick, the time is proportional to the thickness; for example, 3-inch stock takes about three times as

long in the kiln as 1-inch stock. Quarter-sawed stock requires from 25 to 35 per cent longer to dry than plain-sawed. Stock which needs to be dried only to 10 to 14 per cent, such as vehicle material, etc., will require one-fourth to one-third less time than that given in the table. More rapid drying is possible, but not without injury of some kind to the wood. The drying time as here given is not limited by the type of dry kiln but by the physical behavior of the wood itself.

TABLE 1.—*Approximate drying period for 1-inch green and partially air-dry stock to 6 per cent moisture content, under mild conditions in any kind of kiln where circulation is adequate and temperature and humidity are suitably controlled.*

Species.	Drying time.	
	Green from the saw.	Partially air-dry—25 per cent moisture (based on the dry weight of the wood).
HARDWOODS.	*Days.*	*Days.*
Swamp oak	45 to 50	20 to 25
Northern oak	30 to 40	17 to 20
Walnut, cherry	22 to 30	13 to 15
Mahogany, beech	16 to 22	9 to 12
Gum, tupelo	20 to 26	10 to 14
Birch, ash, sycamore	15 to 21	9 to 12
Poplar, basswood, chestnut, butternut, elm, cherry	8 to 10	4 to 6
Maple, hickory	17 to 23	9 to 13
CONIFERS.		
Western larch	9 to 12	4 to 6
Cypress, redwood	10 to 18	6 to 8
Douglas fir, yellow pine, incense cedar, spruce	4 to 6	3 to 4

PILING.

Even circulation is of prime importance, and the manner of piling has a direct influence on the character of the circulation. The lumber must be so piled that the air can pass through the load with the least resistance.

In the water-spray kiln the stock should be piled lengthwise of the kiln on stickers which run across the pile in the direction of the air currents. The stickers should not be less than 1 inch thick for stock up to 1¾ inches thick and 1½ inches thick for stock 2 inches and over.

There is a natural tendency for the air passing through the lumber to descend on account of the cooling effect of the lumber. The pile can be constructed to take advantage of this natural circulation, as by flat open piling or slant piling. In flat open piling the boards are separated horizontally about the width of the stickers, which permits a slight downward or diagonal circulation across the pile. The slant piling allows a more direct path for the moving air than

the open flat piling, while taking advantage of the downward circulation.

For slant piling the pitch should not exceed 1 inch in 5 inches, on account of the tendency of the lumber to slide on the supports. Lumber or plank may be laid edge to edge, but heavy dimension stock should be piled open, as illustrated in fig. 2. The piles should not be over 5 feet wide and 9 feet high.

PRINCIPLES OF KILN DRYING.

The successful kiln drying of refractory woods is absolutely dependent upon the ability of the operator to control and maintain the three essential drying conditions—temperature, humidity, and circulation. Heat is required for evaporation of the moisture; a circulation of air is necessary to carry the heat from the heating coils to the lumber and to carry away the moisture evaporated from the wood; and the relative humidity controls the rate of drying from the surface of the lumber.

TEMPERATURE.

There are two definite reasons for accurately controlling the temperature: (1) Many species of wood have very exacting temperature requirements for successful drying, especially while green; and a relatively slight departure from the desired temperature may result in damaged stock. As the drying progresses, however, relatively higher temperatures can be used without causing damage, and usually fluctuations in the temperature at this time may occur without serious damage. (2) Any increase or decrease in temperature not under the control of the operator, or a difference in temperature at opposite ends of the kiln or in different parts of the pile, will affect the relative humidity, and the drying will not be under control.

HUMIDITY.

In the process of drying the surface of a piece of wood becomes drier than the interior, owing to the resistance of the wood substance to the transfusion of moisture. If the drying occurs in hot, dry air the moisture difference between the surface and center portions of a given piece becomes very great. The surface tends to shrink more than the center, with the result that the stresses which develop cause warping and surface checking in the early stages of the run and honeycombing and permanent casehardening during the final period of drying. To control the drying, therefore, the operator must be able to maintain any humidity desired, independent of the temperature.

CIRCULATION.

Evaporation requires heat. Air is the medium used for conveying this heat to all parts of the lumber pile and for carrying away the

evaporated moisture. The circulation must be positive and ample throughout the pile and reasonably uniform in order to produce equal distribution of heat and humidity. A sluggish circulation means slow drying; stagnant air means no drying; and unequal circulation means unequal drying. This is especially significant in the case of green lumber.

PRINCIPLES OF OPERATION.

In a water-spray kiln the air entering the lumber pile is controlled at the maximum temperature and minimum humidity desired. As the air comes in contact with the moist lumber, it absorbs moisture, which causes a drop in temperature and an increase in humidity. Thus the temperature of the air is somewhat lower and the humidity higher when it leaves the pile than when it enters.

To remove the moisture that has been taken away from the lumber, the air is cooled by passing through the water sprays. The air leaving the spray chambers is saturated at the dew point [2] of the air entering the pile. During the passage of this saturated air over the heating coils the temperature is raised and the relative humidity thereby is lowered. From the heating coils the air passes to the lumber again at the original temperature and humidity. The cycle is thus repeated.

The temperature of the air as it leaves the spray chamber through the baffles is controlled by the temperature of the water admitted through the sprays. The temperature of the spray water itself is controlled by a thermostatic water-mixing valve, which automatically mixes warm and cold water to maintain the desired constant temperature condition; or in certain cases the automatic mixer is made unnecessary because the water may be held at the desired temperature in the well by admitting cold water with the spent water returning from the sprays.

The heating coils are usually controlled by a thermostatic valve placed on the steam supply. The controlling bulb of the thermostat is placed on the entering air side of the lumber pile in which the temperature is to be controlled. The coils are divided into a number of units which are properly valved to be operated separately or together, according to the kind of material to be dried and the temperature required.

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[2] The term relative humidity refers to the ratio of moisture present in the air to the amount of moisture the air can hold, and is expressed in per cent. The amount of moisture that air can hold varies with the temperature of the air. At any given temperature the greatest amount of water vapor that air can hold is fixed, but any less amount than this maximum may occur. Increasing the temperature of air increases its capacity to carry moisture and thus with the same amount of vapor present reduces the humidity. Lowering the temperature decreases its moisture-carrying capacity and increases the humidity. If air which is not saturated is cooled at constant atmospheric pressure, a definite temperature is eventually reached at which the air becomes saturated and any further cooling will cause condensation of some of the vapor into water. This temperature is called the "dewpoint."

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KILN CONSTRUCTION MATERIAL.

The selection or choice of building material depends largely upon the first cost, depreciation, upkeep, and fire hazard. The materials which may be used are:

Wood: Studs sheathed on both sides or sheathed inside and plastered outside. Crib or laminated construction.

Brick: Solid brick, brick and tile, brick with air space.

Tile: Hollow tile walls, plastered outside and inside.

Concrete: Solid concrete or hollow concrete blocks.

The depreciation in kilns, of whatever material they may be built, is much higher than in ordinary buildings, on account of the excessive heat and moisture. In wood kilns the alternate moist and dry conditions swell and shrink the boards, causing more or less working of the frame, loosening of nails, etc. Brick, tile, and concrete walls expand unequally with the heat, causing cracks, through which heat can escape and moisture enter.

Where fire risk is not a consideration and insurance rates will permit, a well-built wood kiln is very satisfactory, wood being a very good insulator, easily repaired, and costing less at first than other materials. Where available, fir, Douglas fir, yellow pine, redwood, cypress, and similar woods with low shrinkage rates should be used for sheathing and sills. Studs, roof timbers, etc., can be of any good straight-grained material. All wood should be thoroughly air dry. Sheathing should be shiplap laid horizontally and nailed twice at each stud, in the middle and at the bottom of the board. Outside walls should be insulated with a good moisture-proof, heat-resistant insulator. The ordinary quilt insulations sewed between so-called waterproof paper have not proved satisfactory in dry kiln construction. The inside walls should be painted with a good moisture and heat resistant asphaltic paint.

Where lumber is relatively plentiful and cheap, as at or near a sawmill, crib, or laminated construction is frequently adopted, the walls being built of 2 by 4 inch or 2 by 6 inch planks laid flat, and the roof of similar material laid tight together. When the kiln is properly built of well-seasoned, well-manufactured stock, this form of construction is slow burning and resistant to heat loss. Inasmuch however, as the material is usually low grade and knotty stock, tight, weather-resistant construction is extremely difficult to obtain. The shrinkage of the walls is excessive, and causes considerable trouble at door jambs and where pipes pass through walls. Figure 1 shows a kiln built of wood, illustrating stud and sheathing and also crib construction.

Brick or hollow tile is available almost everywhere and makes a very satisfactory fire-resistant construction; and where permanency is desired is usually more satisfactory than wood. The brick or tile

should be hard-burned. The walls should be laid up in tempered or cement mortar. The difference in expansion between the inner and outer faces of the exterior walls caused by the difference in temperature will create numerous small cracks, particularly in solid brick walls in cold weather, which should be painted up with an elastic cement rather than mortar. Where tile is used, selection should be made of a type in which the openings run horizontally rather than vertically in the wall. The tile should be properly scored for plastering. Both sides of tile walls should be plastered with cement mortar.

Where kilns over 50 feet long are built of brick, tile, or concrete, it is advisable to build the interior and exterior walls 12 inches thick, particularly where fireproof roofs are used.

Walls of monolithic concrete or concrete blocks are highly absorbent of moisture unless thoroughly waterproofed. It is very difficult to hold a high humidity within the kiln where the walls will absorb moisture readily. The heat loss through such walls is also very great.

Figure 2 shows a kiln with brick walls and wood roof; figure 3, a kiln with tile wall and tile and concrete fireproof roof.

DETAILS OF CONSTRUCTION.

SPRAY CHAMBER.

Whether side or center spray chambers should be selected depends upon the temperatures to be used in the kiln. The side-spray chambers produce a greater and more even circulation than the center-spray type. The side-spray type is recommended for all low and medium temperature runs and for high temperature runs on very green stock. The center-spray chamber is somewhat less expensive to install than the side-spray chamber, which requires extra piping and fittings, and is suitable for kilns where high temperatures are to be used.

Where side-spray chambers are used the inside width should be 12 inches. For center-spray chambers the width should be 15 inches. The height from the bottom of the kiln should not be less than 5 feet 6 inches, and the top of the chamber wall should be about 18 inches above the top of the rail when kiln trucks are used, or 6 inches above the loading floor when trucks are not used.

The spray-chamber walls may be wood, brick, or concrete. Where wood is used, narrow cypress shiplap $1\frac{1}{8}$ inches thick laid vertically (see fig. 2) will probably be found most satisfactory, and should be well nailed with cut nails to 2-inch and 4-inch cypress cleats. This wood should be set green. Hard-burned brick walls 4 inches thick laid in cement mortar and plastered with cement plaster prove satisfactory, as do also integral waterproofed concrete walls 3 or 4 inches thick. (See fig. 5.)

The spray-chamber walls should be braced with piers from 4 to 5 feet apart, carrying the steel support of the rails.

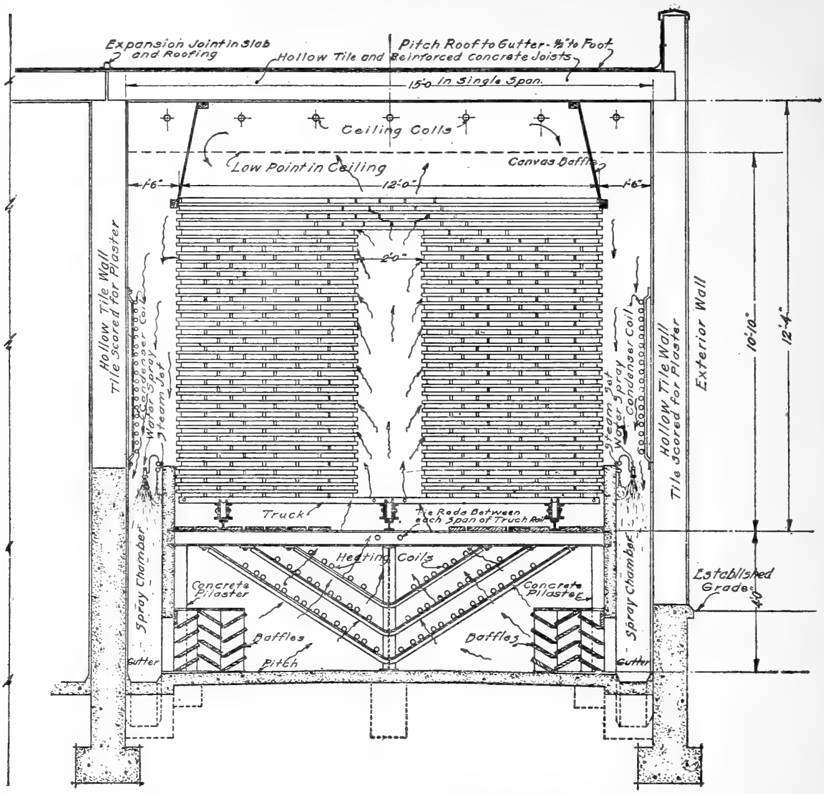


FIG. 5.—Typical cross section. Tile walls, concrete spray chamber, concrete and tile roof. Flat open piling.

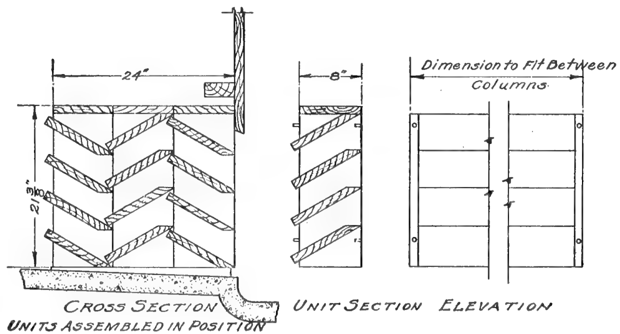
No paint or other coatings or preservatives should be used in the spray chamber, as the hot water and steam will cause small particles to wash down to the well and make trouble in the pumps and sprays.

BAFFLE BOXES.

The function of the baffle boxes is to remove any fine spray or mist from the air coming down the spray chamber before it returns to the coils.

The boxes are usually built of wood, but in some cases metal has been used. Metal is liable to rapid deterioration, on account of the acid fumes given off by certain species when seasoning. Even copper will disintegrate very rapidly. Cypress, Douglas fir, redwood and pine have proved most suitable, and white cedar and western red cedar are satisfactory.

The baffles should be built up in interchangeable sections, dressed 1-inch lumber fastened with brass screws being used. The boxes should fit between the supporting piers tight against the spray chamber wall, but should not be fastened in place. (Fig. 6.)



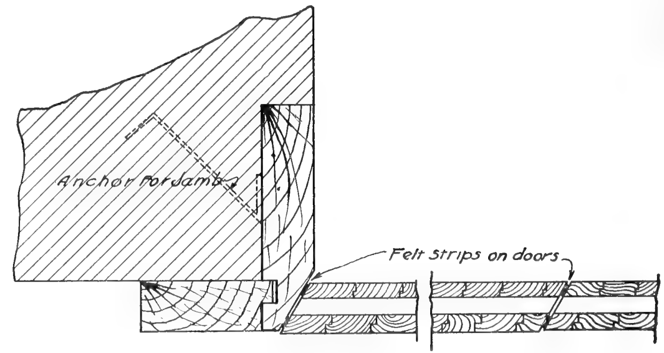


FIG. 6.

Detail of baffle boxes. To be built of cypress or white pine and put together with cut nails. Sections should not be fastened together.

Detail of jamb for wood doors, 3-ply, $\frac{7}{8}$-inch stock.

The detail of the baffle boxes on the accompanying drawings illustrates a common method of construction.

No paint should be used on the boxes.

DOORS.

The doors should be easily operated, tight fitting, and well insulated. They should be so designed that slight working due to expansion and contraction on account of heat and moisture changes will not cause them to stick and bind. A loose-fitting, leaky door may cause enough damage in one charge of valuable wood to pay for a new door.

LOADING DOORS.

Steel, wood, and canvas are the most common materials for loading doors, but sometimes asbestos on a steel or wooden frame or various patent composition doors are used. Steel doors should be insulated on the inside with a moisture-proof insulation at least 2 inches thick. Wood doors are usually built of three thicknesses of $\frac{7}{8}$-inch stock laid diagonally. Such a door, if covered with tin, is practically fireproof and lowers insurance rates. If the door is not tinclad, some moisture-proof insulation should be used between the plies. Canvas which has been dipped in linseed oil is satisfactory. Canvas doors are made double with an intervening air space of about a foot, and are hung on rollers. The edges are clamped down when the kiln is in operation.

The doors may be hinged to swing out or built to slide on rollers or to elevate vertically by balance weights. Sliding doors can not be used where the operating valves and thermostats are on the wall between the loading doors of adjacent kilns. Swinging doors should be on special or garage hinges and held by refrigerator door locks. For the roller doors there are several very satisfactory patented door carriers.

INSPECTION DOORS.

The frequent inspection of stock and the reading of auxiliary thermometers in the kiln is very apt to be neglected unless some easy method of getting into the kiln is provided. For this purpose there should be a small door in each compartment for obtaining access to the kiln without having to open the main doors. Large doors are often too heavy for one man to handle and impossible to open or close from the inside. Small doors can be built in the main door and need not be over 2 feet 6 inches by 5 feet. They should have latches or fastenings which may be operated from the inside as well as outside of the kiln, so that an operator will not be in danger of being closed inside the kiln.

ROOFS.

The roof may be built of wood, concrete, or tile and concrete.

Wood roofs should be ceiled on the underside to prevent excessive heat loss; and in case of long kilns it is advisable to fur down the ceiling to make it level and create an ample air space between the ceiling and the roof. (See fig. 1.) Such space should have grated openings for ventilation; otherwise it becomes saturated with moisture and destroys the insulating effect.

The absorption of moisture and the heat loss is much less in the tile and concrete roofs than where concrete slabs are used and the construction is much lighter. By casting the roof slab flat and using a cinder filling graded to gutters for roof drainage, a level ceiling can be obtained.

It is advisable to build tile or concrete roofs in such a manner as to have expansion joints over each bearing or division wall; for in monolithic roofs with a solid continuous slab the expansion is multiplied and causes the outer walls to be pushed out of alignment.

FLOORS.

The floor of the kiln should be concrete, pitched toward the gutter one-fourth inch per foot. It is advisable to lay the floor on a cinder foundation; in the absence of cinders sand should be used. The floor need not be over 3 inches thick, but should be troweled smooth to permit flushing with a hose.

GUTTERS.

The gutters should be the full width of the spray chamber, at least 3 inches deep at the shallow end and pitch evenly to the drain not less than 1 inch in 8 feet. A floor-drain grating, without trap, should be set over the opening to the drain piping. For installation of drain for return water see "Water supply."

WELLS.

The wells should be built of concrete, made watertight with integral waterproofing. For size and shape see "Water supply."

ELECTRIC WIRING.

Electric lights spaced from 20 to 25 feet apart along the spray chamber make it easy for the operator to examine the sprays readily to see whether all heads are in operation and also to note the condition of the lumber. A switch should be provided outside the door. All fittings inside should be waterproof or marine type and all wire lead-covered.

INSULATING MATERIALS.

Materials for insulation in kilns should be nonabsorbent and capable of standing high temperature and moisture conditions without damage. Ordinary building paper is practically worthless. Water-

proofed building paper and felt will last only a short time. Sheathing quilts composed of some insulating material sewed between sheets of paper will deteriorate very rapidly, and most of the other insulating materials intended for ordinary building work are of little value and short lived. Plaster, where used, should be of cement, not lime. If possible it should be somewhat porous and elastic. Canvas used for baffles over the lumber pile gives long service. Where used for doors, it should be waterproofed. Wood is a very good insulator, and is satisfactory around doors or other places even where there is considerable moisture. Strips of felt placed around the door jambs make a very good joint to prevent leakage, and are easily replaced when they become "dead." Such strips should last about two years.

PAINTS AND COATINGS.

The paint used for inside work in kilns should be capable of standing high temperatures under moist conditions without softening, flaking, moulding, or otherwise deteriorating. Some paints become dull, chalk, and rub off. Others retain their luster and serviceability for a year or more. A high melting asphaltum paint is excellent not only for the iron pipes, but also for the steel supports and rails, side walls, and ceilings, whether of wood, brick, tile, or concrete.

The pipes and ironwork should be kept well protected against rust by yearly painting and frequent retouching where necessary. White lead and linseed oil paints do not last under dry kiln conditions. Red lead and linseed oil may be used for iron work.

HEATING INSTALLATION.

GENERAL TYPES OF SYSTEMS.

The source of heat in most dry kilns is steam, distributed through a high pressure, low pressure, or vacuum system. If the pressure carried is over 10 pounds, the system is called a high-pressure system; if less than 10 pounds a low-pressure system.

Vacuum systems require special apparatus and patented fittings, and their success depends largely upon the working of such specialties. As vacuum systems are usually patented and in most cases installed by the owners of the patents, their merits will not be discussed here.

Vacuum and low-pressure steam systems are usually used for kilns where the maximum temperature desired is below 150° F. and high-pressure systems for higher temperatures.

If available, low-pressure exhaust steam is the most economical method of heating low-temperature kilns. Such exhaust steam is available only during the working hours of the plant, however, and to avoid shutting down the kilns when the plant is not in operation the system should be connected through pressure regulating valves directly with a boiler in which steam is maintained continuously. Such a by-pass is illustrated on figure 7.

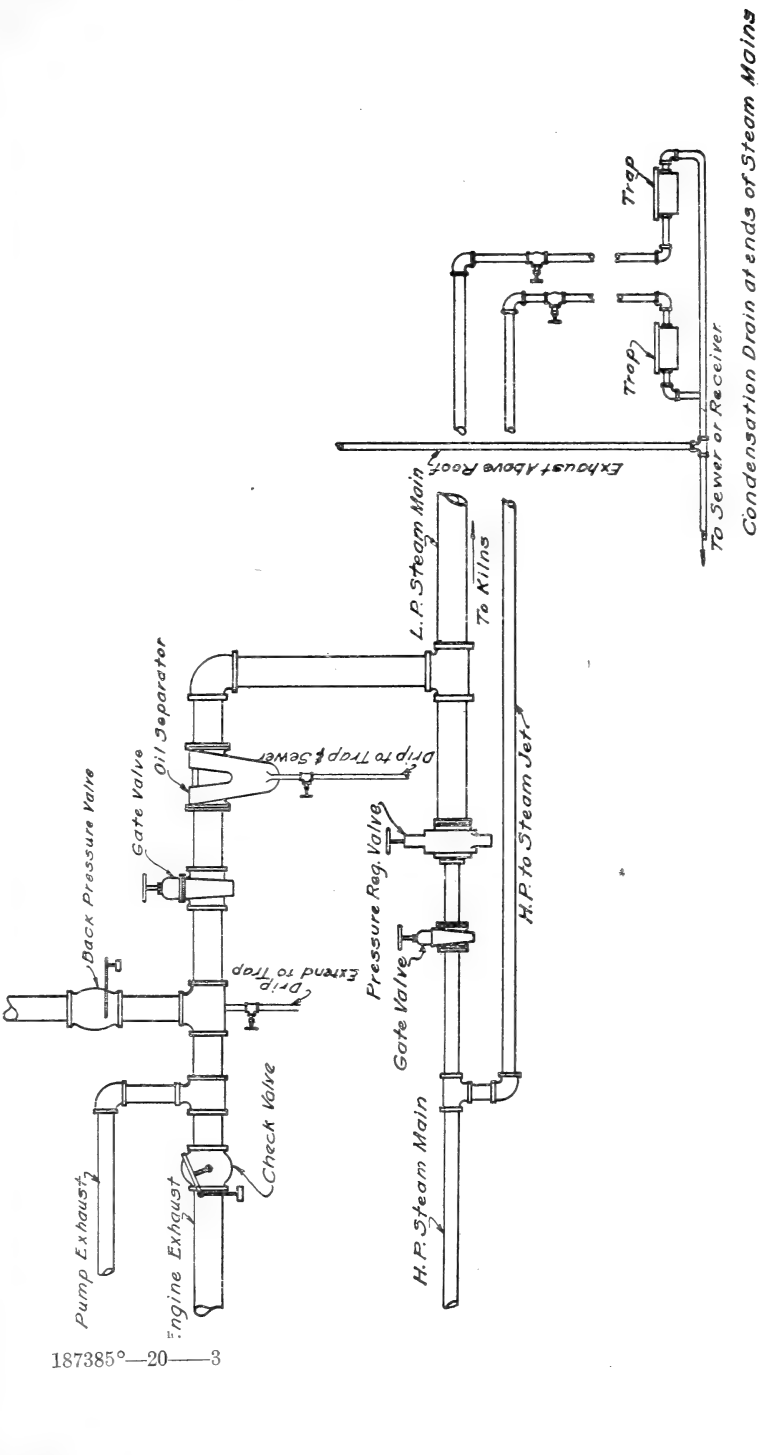


FIG. 7.—Method of connecting engine exhaust to steam main. With auxiliary H. P. supply.

HEATING COILS.

The necessity of proper planning and installation of the heating equipment can not be too strongly emphasized. Whether or not a kiln can dry refractory woods successfully is absolutely dependent upon the heating installation. Even temperatures must be maintained, otherwise it is impossible to maintain an even control of the humidity. The heat from the coils must be evenly distributed throughout the kiln from end to end if any degree of uniformity in the drying is to be obtained. The critical period in the seasoning of green stock is during the early stage of drying, when low temperature and high humidities are necessary. A few degrees difference in temperature in different parts of the kiln at this time means a very marked difference in the humidity. This may result in saturating and moulding the lumber in one end of the kiln and checking and honeycombing it at the other. Under such conditions it is impossible to dry the lumber without great loss. All refinements that are introduced in a dry kiln are for the purpose of bringing about even distribution of heat and humidity. The coils must be so designed and installed that the temperature of the air after it has passed over them will be the same throughout the length of the kiln.

There are two general types of coils in common use, the header and the return bend.

HEADER TYPE.

The usual manner of installing header coils is to start the pipes from a supply header at one end of the kiln and bend them down into a drainage header at the opposite end, from which a drain leads to a steam trap or pump. The steam enters the supply header at one end of the coil and starts through all of the pipes more or less simultaneously. Naturally, the steam loses heat very rapidly on account of the amount of radiation surface exposed, and before it reaches the return header it has become cooled far below the temperature at the supply header. Oftentimes the steam is condensed before it has gone one-third the length of the coil, with the result that one end of the kiln may be 15 or 20 degrees hotter than the other end. This means a very low humidity at the hot end and a high humidity at the cooler end, a condition that would be disastrous in a kiln loaded with heavy green oak or other refractory wood.

Header coils may be used for medium and high temperature runs where kilns are not over 25 feet long. They are not practical for high humidities in low-temperature runs.

RETURN BEND TYPE.

In return bend coils the pipes extend continuously from end to end of the coil and are connected like the folds of an accordion or bellows, with return bends. Obviously the steam has to travel the

full length of the coil back and forth until condensed. Thus the temperatures are even from end to end. A return bend coil may be throttled without interfering with the end-to-end-heat distribution in the kiln. This is not the case with the header system.

The return-bend type is somewhat more difficult to install than the header type and is more limited as to the position in which it may be placed to drain properly. These factors, however, are of no consequence in comparison with the uniform temperatures obtained and the flexibility of control.

The return-bend type of coils is recommended, and its use will be assumed hereafter in this bulletin.

LOCATION OF COILS.

The recirculating air leaving the baffle plates should be so controlled and directed as to travel directly toward the entering air flue. The heating coils should be in the path of this moving air and not close up under the floor under the lumber pile, where the circulation is usually more sluggish.

Whether the center or side spray chambers are installed, the heating surface is separated into two main sections, one on each side of the kiln, in order that it may lie in the path of the moving air. Where side-spray chambers are used (see figs. 2 and 5), the coils are disposed across the cross section of the kiln in the form of a V. When a center-spray chamber is used (see fig. 1), the form is inverted.

MULTIPLE UNITS.

For flexibility of temperature control the total heating surface should be divided into three units of varying sizes, regardless of the division into sections mentioned above. Each unit consists of two sets of coils, one on each side of the kiln, and is supplied through an independent valve. The units are proportioned so that the radiation in the upper set is about 25 per cent, the middle set about 35 per cent, and the lower set about 40 per cent of the total.

SUPPORTS.

The coils should be supported by hook plates or other equally substantial supports placed so that the coils will drain in a continuous fall in the direction of the flow of steam. Any possibility of sag in the pipe should be avoided. The greater the slope the better, but it should not be less than one-tenth of an inch to each foot of length.

ESTIMATING HEATING SURFACE REQUIRED.

The amount of radiation required may be determined by using the following factors, or by means of constants and the formula given on page 21. The factors entering into the calculation of the heating surface required are maximum temperature, minimum dew-point

temperature, velocity of air over coils, and steam pressure to be used. These being known, the heating surface required to raise the saturated air from the lowest dew-point temperature to the maximum entering air temperature may be determined. To this must be added the heating surface required to offset heat losses due to type of construction, climatic conditions, etc.

The maximum temperatures desirable in the kiln vary, according to the product being dried, from 120° F. for thick, refractory stock to 180° F. for the more easily seasoned woods.

TABLE 2.—*Maximum final temperatures for various species.*

Character of wood.	Product and species.	Maximum temperature.
		° F.
Very refractory woods	Heavy stock—oak for vehicles	120
Do	Ordinary thicknesses—swamp oaks and woods of the same class.	130
Refractory woods	Highland oak and woods of t e same class	145
Average woods	Maple, mahogany, walnut, ash, elm, beech, tupelo, sycamore, hickory, cherry, redwood, and cypress.	160
Easily seasoned woods	Birch, gum, chestnut, poplar, basswood, butternut, etc., spruce, pine, fir, hemlock, etc.	180
1 and 2 inch softwoods	Douglas fir, pine, fir, etc	200–230

Where four kilns or less are installed, sufficient heating surface should be provided to heat the kilns to the highest maximum temperature suitable for the most easily seasoned woods used by the plant. Where more than four kilns are built, it would probably be economical to design part of the installation for high temperatures for easily dried woods and the rest for low temperatures for slow-drying heavy stock.

The velocity of the air over the coils, the water sprays being located and the water pressure maintained as recommended in this bulletin, may be assumed to be about 80 feet per minute at 45 pounds water pressure at the spray heads.

Careful consideration should be given the problem of heat loss, the following factors being borne in mind and it being assumed that the battery of kilns is built in the open and unprotected by surrounding buildings:

1. A single kiln is exposed on all sides, but in a battery of kilns the end compartments have exposure on one side only.

2. The exposure at the ends of the kilns should be provided for in excess of the regular heating coil.

3. The heat loss through the roof should be provided for by a special ceiling coil.

4. There will be some loss of heat through the floor of the kiln below the coils, which must be provided for.

5. In the case of a single kiln or the end compartment of a battery of kilns having side spray chambers, the heat loss through the outside wall need not be considered, as it actually assists the water sprays in lowering to the dew point the air leaving the lumber. Except in extreme cases, the heat passing off from the lumber in the form of vapor is sufficient to take care of radiation losses through the ceiling and walls of the kiln.

The following formula and constants have been established from the experience obtained in connection with design of commercial kilns and from results of tests made in laboratory kilns. Theoretically it is not correct to consider that the heat required is proportional to the size of the kiln, since it varies directly with the quantity of air in circulation passing over the heating coils; the greater the circulation the greater the heat radiated per square foot of heating surface. However, since so many local variable factors influence this quantity in different kilns, and since the circulation in the water-spray kilns may be assumed as approximately equal in different cases, it has been found that an empirical rule such as here given is sufficiently accurate for estimating purposes.

$$W \times H \times K = R_1$$

W=Width of the kiln above rail, in feet.
H=Average height of kiln above rail, in feet.
K=Constant from table below.
R_1=Radiation surface required per linear foot of kiln.

TABLE 3.—*Constant "K."*

Maximum temperature and 25 per cent humidity.	Pounds steam pressure.			
	2.5	7	30	80
	Constant.	*Constant.*	*Constant.*	*Constant.*
120	0.10	0.075	....	....
130	.166	.130	0.090	0.055
145	....	.166	.125	.085
160	....	....	.166	.120
180	....	....	....	.166

The above formula gives the radiation per linear foot of kiln. To find the number of pipes required:

$$\frac{R_1}{A} = P$$

A=area of 1 foot of pipe (see Table 4).
P=number of pipes required in cross section of kiln.

The following table is given for the convenience of the designer in figuring pipe areas:

TABLE 4.—*Square feet of radiating surface per linear foot of pipe.*

Diameter of pipe.	Radiating surface per linear foot.
Inches.	*Sq. ft.*
$\frac{3}{4}$	0.275
1	.346
$1\frac{1}{4}$	.434
$1\frac{1}{2}$	.494
2	.622
$2\frac{1}{2}$	.753
3	.916

One and one-quarter inch pipe is used most frequently for return-bend coils up to 30 feet in length and proves very efficient. On account of friction 1-inch pipe should be used only where the coils are small. Large or extra-long coils should be of $1\frac{1}{2}$-inch pipe.

As an illustration of the above method of calculating radiation, take a kiln which is to dry 2-inch oak and in which the maximum temperature should not exceed 145° F. The kiln is to be 15 feet wide and an average of 11 feet above the rails. There will be about 7 pounds steam pressure available at the kilns. From the table we find that for 145° F. and 7 pounds steam pressure the constant K is 0.166. Therefore, the formula becomes:

$15 \times 11 \times 0.166 = 27.39$ square feet radiation surface per linear foot of kiln.

If $1\frac{1}{2}$-inch pipe is selected for the coil, the number of pipes used will be:

$$\frac{27.39}{0.494} = 54$$

The total amount of radiation surface in the heating coils will be the inside length of kiln multiplied by the radiation per foot. Assuming 39 feet for the length of kiln inside of walls, the total radiation in coils below rails becomes $39 \times 27.39 = 1{,}068.21$ square feet. The coils will be about 38 feet in this instance, and the return-bend fittings will make up the rest of the radiation.

PIPES AND FITTINGS.

The best wrought-iron pipe should be used for work inside kilns. Galvanized pipe or fittings should not be used, as the fumes given off from many woods when drying decompose the coating.

The pipe should be well painted with good high-temperature-melting paint.

The return-bend fittings should be of the type known as "open pattern," as their larger radius tends to reduce resistance to the travel of the steam.

In assembling coils all pipes should be laid to drain toward the return pipe, and have no air or water pockets which can interfere with the operation of the coils.

CEILING COILS.

Where the roof is exposed to cool or cold outside atmospheric conditions condensation forms on the ceiling of the kiln, drips on the lumber, and makes the control of humidity difficult, as well as staining the lumber. To offset this condition, ceiling coils consisting of $1\frac{1}{4}$-inch pipes 2 feet to 2 feet 6 inches apart should be installed about 3 inches below the ceiling, running across the width of the kiln and the full length of the kiln. The pipes can be connected with tees and nipples in the form of a header coil.

The steam supply to the ceiling coil does not require thermostatic control, but should always be taken through a globe valve from the boiler side of the thermostat controlling the heating coils.

In kilns over 40 feet long the ceiling coils should be fed in the middle.

The condensation return should not in any case drain into the trap for the heating coils; it must drain through a globe valve into a separate trap.

The size of the supply and return may be determined from Table 5; in no case, however, should the supply be less than $1\frac{1}{4}$ inch or the return less than 1 inch.

STEAM MAINS.

One steam main only is required when high-pressure steam (where pressure is 30 pounds or more) is used in the coils, but where low-pressure or exhaust steam is used a high-pressure and a low-pressure main are required. This is necessary because the high-pressure steam is necessary in the steam jets.

Where an exhaust system is used the exhaust steam from the engine and pumps is passed through a check valve, back-pressure valve, gate valve, and water and oil separator. Live steam is also connected into the main through a gate valve and pressure-reducing valve to supplement the exhaust steam when the engines are not in use, or at any other time when necessary. One method of connecting the engine and pump exhaust with the steam main is shown on figure 7.

Both low and high pressure mains should be drained at the far end through a gate valve to a suitable trap after the supply to the last coil has been taken off, as illustrated on figure 7.

The steam main should pitch in the direction of flow 1 inch in 30 feet at least and 1 inch in 10 feet where practicable.

Where high-pressure steam is used a pressure regulating valve should be placed on the main to balance and control the pressures in the system.

STEAM SUPPLY TO COILS.

The steam supply pipe to the coils should be taken from the top of the steam main to avoid drawing dirt and condensation into the system. Where the steam main is overhead this will also allow provision for expansion.

Where automatic temperature regulation is used the thermostatic valve is placed on the steam supply to each kiln so that it controls the supply to all coils.

After passing the thermostat, the separate supply to each coil unit should be taken off through independent valves, in order that the different units may be used separately or together. Care should be exercised to balance all supplies as to size and resistance to flow of steam, in order that no coils may be starved to the advantage of other coils.

Where the coils are over 40 feet long they should be divided in two sections lengthwise and supplied from the center of the kiln, as shown in figure 8. In this case the supply pipe should be covered with waterproof and heat-proof insulator between the operating room and the connection to the coils proper, otherwise the exposed heating surface at the two ends of the kiln is unbalanced.

STEAM MAIN SIZES.

In determining the size of steam mains, first compute the size of supply necessary to each kiln and then the size of main required to supply all kilns, and reduce in size in proportion to the size of supplies taken off.

Consideration must be given to the following points:

1. The smaller the main the greater the resistance due to friction and to consequent back pressure in the system.
2. Conversely, the larger the main the less the resistance and the greater the efficiency, but also the greater the cost of installation.
3. The greater the length, the greater the resistance due to friction, and the greater the necessity for larger pipe.
4. Bends, valves, or other equivalent obstructions increase the resistance due to friction and must be compensated for.

For pressures up to 5 pounds gauge, which is the upper limit desirable for exhaust systems, the size of mains and supplies may be determined from the table following by A. R. Wolff.

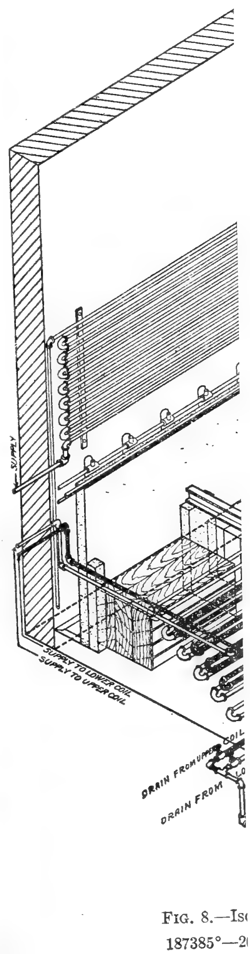


FIG. 8.—Is

187385°—2

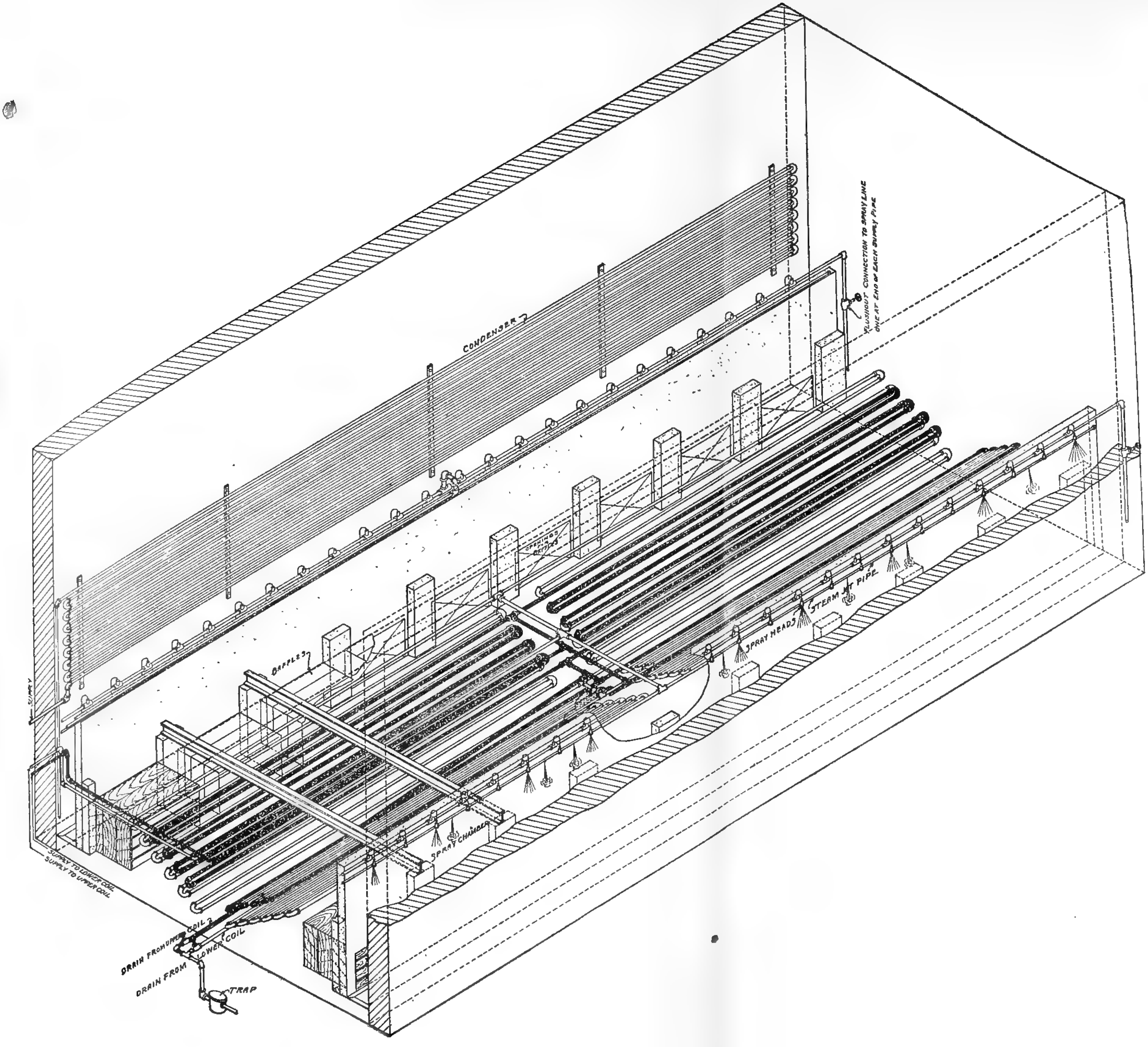


FIG. 8.—Isometric view of interior of kiln, showing two coils with supply and drain located in center of kiln used when kiln is over 40 feet long.

187385°—20. (To face p. 24.)

TABLE 5.—*Capacity of steam pipes 100 feet in length with separate returns.*

Diameter of supply.	Diameter of return.	Radiating surface.	
		2 pounds pressure.	5 pounds pressure.
Inches.	*Inches.*	*Sq. feet.*	*Sq. feet.*
1	1	36	60
$1\frac{1}{4}$	1	72	120
$1\frac{1}{2}$	$1\frac{1}{4}$	120	200
2	$1\frac{1}{2}$	280	480
$2\frac{1}{2}$	2	528	880
3	$2\frac{1}{2}$	900	1,500
$3\frac{1}{2}$	$2\frac{1}{2}$	1,320	2,200
4	3	1,920	3,200
$4\frac{1}{2}$	3	2,760	4,600
5	$3\frac{1}{2}$	3,720	6,200
6	$3\frac{1}{2}$	6,000	10,000
7	4	9,000	15,000
8	4	12,800	21,600
9	$4\frac{1}{2}$	17,800	30,000
10	5	23,200	39,000
12	6	37,000	62,000
14	7	54,000	92,000
16	8	76,000	130,000

The amount of heating surface a steam main will supply is reduced in excessively long runs or where frequent obstructions occur. For pipe of greater length than 100 feet, reduce the amount of radiation for a given diameter pipe according to Table 6.

TABLE 6.—*Constant for reducing radiation on account of length of pipe.*

Length of pipe.	Reduction factor.
Feet.	
200	0.71
300	.58
400	.50
500	.45
600	.41
700	.38
800	.35
900	.33
1,000	.32

In estimating the length of mains and supplies consider the length of pipe increased by all obstructions such as elbows, tees, valves, etc. Such increase in length may be expressed in terms of diameters as follows: Right angle elbows, 40 diameters; globe valves, 125 diameters; tees, 60 diameters.

The steam main should be gradually increased in size as it approaches the source of supply in proportion to the amount of radiation taken off to supply the kilns on the main.

There are two rules in common use by steam fitters for determining the approximate size of steam mains and supply pipes which will give fairly satisfactory results when applied to short runs of pipe.

Rule I.[3]—Diameter of steam main in inches should equal $\frac{1}{10}\sqrt{\text{Radiating surface in square feet.}}$

[3] Mr. George Babcock.

This allows a velocity of about 25 feet per second and is used for low-pressure or exhaust systems.

Rule II.[4]—Allow a constant of 0.375 square inch per 100 square feet heating surface in coils for exhaust or low-pressure steam. Allow a constant of 0.19 square inch per 100 square feet heating surface in coils for high-pressure steam.

CONDENSATION RETURN.

The water of condensation from the heating coils contains a considerable amount of heat, and the question of saving this heat by returning the water to the boiler is one of economy and efficiency. This question can only be decided by the engineer or architect designing the installation, who will be familiar with local conditions, such as cost of water, distance between kilns and boiler, whether gravity or pump return to receiver, cost of installing return pumps, traps, receivers, etc.

The return from each unit pair of coils should be drained separately through a swing check valve and a globe valve, after which the drains may be connected and extended to a separate trap for each kiln. The ceiling coil must drain into a trap separate from that of the heating coils. The proper size of return pipes may be found in Table 9.

TRAPS.

There are a great many traps on the market which will give quite satisfactory results when properly installed, and the type selected must depend upon the conditions occurring in each individual case. For low-pressure systems, thermostatic, ball, float, bucket, and tilt traps of the nonreturn type are used; while for high pressures the tilt trap gives the most satisfaction, though bucket traps may be used.

All traps give more or less trouble, on account of their becoming choked with scale, dirt, or other foreign matter, and require frequent inspection. In this respect the tilt trap is superior to the others; for it tilts at each discharge so that the operator can determine at a glance whether it is working properly. This type of trap is more easily cleaned than most other types. However, more height is required between the coils and waste for this trap than for other types, and it should be used only where at least 1½ feet of height is available between condensation return and floor.

If the condensation water is to be wasted, the traps for low-pressure systems should be connected to the sewer in the most convenient manner, preferably through a small basin. If the condensation is to be returned to the boiler, the traps are connected to a receiving tank or pump.

If a thermostat is used on the steam supply, the trap must have a check valve and discharge under a water seal; otherwise air will be

[4] From Van Nostrand's Science Series No. 68.

sucked up into the trap when the thermostat is closed, and the system will become air bound. For high-pressure steam, connect waste to the vent pipe, one end of which is open to the outside atmosphere, the other end in a water seal. This permits any steam passing through the trap, or vapor from the hot water, to escape outside the operating room.

The proper operation of traps is of utmost importance; for if they fail to function properly, uniform heating is impossible.

AIR RELIEF VALVES.

To get the highest efficiency from the heating coils some means of automatic removal of the air must be provided. Pet cocks and valves are sometimes used but are apt to be neglected by the operator. There are a number of automatic valves on the market which give perfect satisfaction.

In determining the type of air valve to be selected the steam pressure used must be considered, and where a thermostat is used on the steam supply, the air valve must seal against a vacuum, and not allow any air to enter the coil.

The air relief valve should be located near the condensation trap, since air is heavier than steam at the same temperature, and will therefore gather in the lowest part of the coils. If possible, the relief valve should be accessibly placed outside the kiln.

TEMPERATURE REGULATION.

Close and accurate control of humidity can be maintained only when the kiln temperatures are under absolute control of the operator. Temperatures may be controlled by "hand," by pressure-regulating valves, or automatically by means of thermostatic valves.

For hand control globe or gate valves are operated to allow more or less steam into the system. With this method of control there is considerable variation in the temperatures obtained. Such control means constant attention of the operator and otherwise is very imperfect. The only feature recommending it is the saving in first cost. Figure 9 illustrates a kiln with hand-controlled heating coils.

Pressure regulating valves are slightly better than hand control, as they balance the pressure in the system, thus regulating the amount of heat given off. With such means of control it is very difficult, however, to maintain low temperatures accurately. The control of humidity is jeopardized at the most critical period of drying and the temperature rises or falls gradually at all times, seriously disturbing the control of drying.

The most practical form of temperature regulation is by means of thermostats, which automatically operate special valves to admit or shut off steam as the kiln temperatures fall or rise. A thermostat

consists of both an expansive element, which expands and contracts under slight temperature changes and is placed in the kiln where the temperatures are to be controlled, and a special valve outside the kiln on the steam-supply pipe. The effect of expansion or contraction in the expansive element is transmitted either by a system of levers or by fluid pressure through a fine tube to the special valve, which is operated either directly or by an auxiliary system of compressed air. fluid, or electricity.

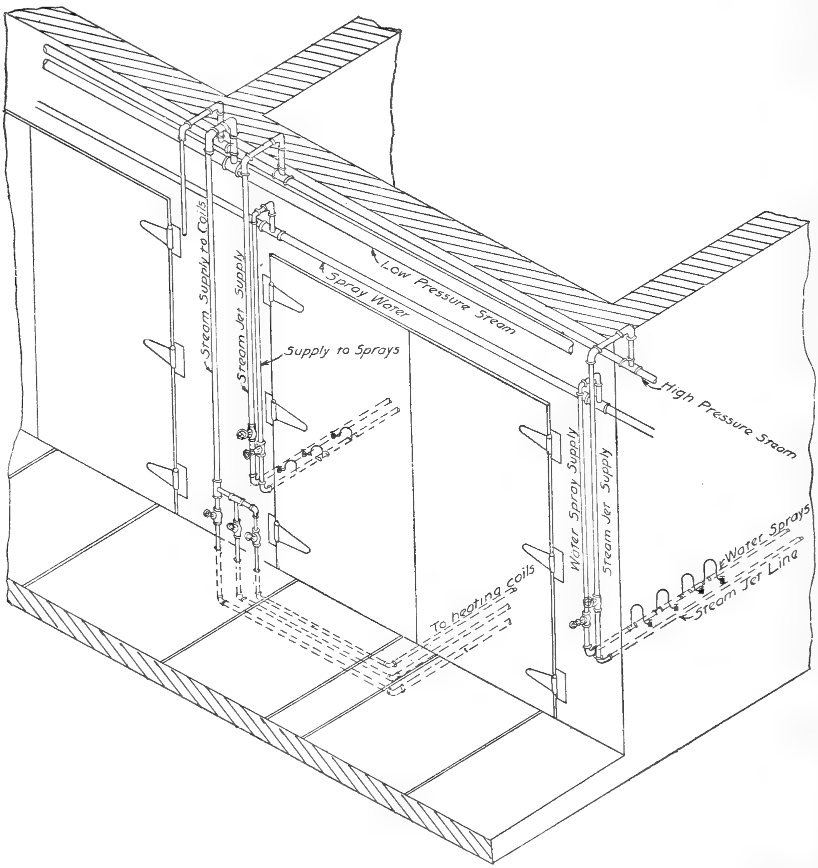


FIG. 9.—Simplified humidity control. Complete connections for one kiln of a series. (See page 40.)

The method of actuating the valves divides the thermostats into two main types—the direct-acting, self-controlled type and the type actuated by an auxiliary or relay system of air, water, or electricity. In the direct-acting class the pressure of the expansive element, which may be saturated vapor, gas, or liquid, operates the valve directly through a system of levers or an accordion bellows. In the relay system the expansive element controls the auxiliary pressure system, which actuates the steam valve.

The selection of the type of thermostat depends upon the temperature range of the kilns. This in turn depends on the variety of stock being dried and the availability of suitable air pressure, etc. The direct-acting thermostats have a temperature range covering from 60° to 80° F. This range is sufficient where one kind of material is being dried. It is not sufficient where the kiln is used for a low-temperature run, as oak, and then for a high-temperature run, as yellow pine. The air-controlled type is actuated by diaphragm motor valves, with air pressure, and has a temperature range covering from 150° to 250° F., wide enough to include the drying temperatures suitable for any wood. An air pressure of 15 pounds gauge is required to operate the valves on the steam supply, but the size of the diaphragm must be suited to the steam pressure, whether high or low.

Where the air-operated type is installed, a reverse acting diaphragm valve, kept open by the air pressure, should be placed on the steam supply, so that it will close off the steam entirely in case of failure of air supply. The water-operated type is similar in action and temperature range to the air-controlled type but is liable to get out of order on account of clogging with dirt, sediment, or grit. The electrically-operated type at present available is hardly suitable for dry-kiln use, since it does not throttle the steam through a graduated valve but closes it off entirely or opens it up full, through a positive-seating valve. There is also considerable danger of failure in contact, which would mean ruin to the lumber. The possibilities of this type for dry-kiln use, however, have not been fully developed.

The control bulb of the thermostat should be placed in the entering air flue and in such a position that its action will be positive and immediate. It is well to shield it against direct radiation and from effects of cold walls or wet lumber. Where the temperature changes of the thermostat are controlled by a key at the bulb inside the kiln an extension handle should be installed at some convenient place outside the kiln to facilitate operation.

STEAM CONSUMPTION.

HEATING COILS.

An estimate of the approximate amount of steam required to heat a kiln to the temperatures given in Table 7 may be determined by the formula:

$$\frac{R_1 \times D \times k}{T} = S$$

When R_1 =Total radiation surface in kiln in square feet.

D =Difference in temperature between steam and air entering lumber pile, in degrees Fahrenheit.

k =Constant from Table 7.

T =Latent heat of steam, B. t. u.

S =Pounds of steam condensed per hour.

TABLE 7.—*Constant k.*

Pounds steam pressure per square inch, by gauge	2.5	7.0	30	80
Latent heat of steam in B. t. u.	965	956	928	890
Temperature of steam (degrees F.)	220	232	274	324
Kiln temperature.	B. t. u. given off per square foot radiation per degree difference in temperature=k.			
°*F.*				
120	2.6	3.0		
130	2.2	2.6	3.0	4.0
145		2.2	2.6	3.0
160			2.2	2.6
180				2.2

For instance, a kiln 39 feet long inside has 1,068 square feet radiation in the heating coils, 7 pounds steam pressure available, and 145 degrees maximum entering air temperature. The difference in temperature between the steam in the coils and the entering air or flue temperature is $232-145=87$ degrees Fahrenheit. Therefore the formula becomes—

$$\frac{1068\times87\times2.2}{956}=216.1 \text{ pounds}$$

steam per hour.

CEILING COILS.

The ceiling coil steam consumption can be approximated with sufficient accuracy by the same method and the same constants. The amount of steam consumed during the early stages of a kiln run, when temperatures are lower and humidities higher, is about one-half as much per hour as under maximum temperature and minimum humidities. Allowance should be made for the radiation from all exposed steam mains and supplies.

STEAM JET.

The steam jet line consists of a pipe running the full length of the spray chamber and located near the sprays, as shown in the cross sections (figs. 1, 2, and 5). This pipe is perforated with ⅛-inch holes at intervals of 12 inches, so as to discharge steam straight down the spray chamber. For kilns up to 30 feet long 1-inch pipe should be used, and for kilns over 30 feet long 1¼-inch pipe. For kilns up to 50 feet in length the spray pipe should be fed at one end and capped at the opposite end. For kilns over 50 feet long the steam should enter the jet line at the middle of the kiln and both ends should be capped.

The function of the steam sprays is to condition the lumber both prior to and during the drying operation. They may also be used

to increase the humidity in the kiln when the water in the well is not sufficiently hot to hold the desired humidity, but otherwise should not be used in conjunction with the water sprays or with the condenser.

By placing the steam jet in the spray chamber as shown, a strong, positive circulation of air is produced during the steaming period, while the proper temperature and humidity conditions are maintained throughout the lumber pile.

The supply to the steam jet line is taken from the high-pressure main direct, as high-pressure steam is necessary, and, if desired, may be by-passed through the thermostat to facilitate control of temperature when steaming with the coils turned off.

WATER SUPPLY.

WATER SPRAY.

The water sprays, which are the essential feature of this kiln, perform two distinct functions. (1) They create circulation by the condensing effect produced and by the force of the spray down the chamber, and (2) they control humidity. The principle of their operation has been fully described on page 9.

With a pressure of from 45 to 50 pounds at the spray heads the velocity of the air down the spray chamber averages between 120 and 140 feet per minute. The pressure of the water available at the spray heads should not be less than 45 pounds, and from 50 to 60 pounds is desirable.

As a medium for controlling the humidity in the kiln, hot and cold water are required for circulation through the spray. The water is mixed to the proper temperature in a thermostatic water mixer.

There are two methods of controlling the temperature of the spray water itself—(1) by a thermostatic water-mixing valve on the water supply line to each kiln, which automatically mixes warm and cold water to maintain the desired temperature condition; (2) by mixing cold water with the spent water returning from the sprays to the well. The second method is adapted only to kilns in which the battery is designed to dry one thickness of stock and using only one temperature schedule, such as heavy oak bolsters, at low temperatures and high humidities.

The water from the sprays collecting in the drain flows by gravity to a well, from which it is recirculated back to the sprays by means of a pump. As the spray water picks up heat in cooling to the dew point the air which has passed through the lumber pile and then into the spray chamber, the water returning to the well establishes the hot water supply needed for low-temperature runs. This drainage water is not hot enough for high-temperature runs when high

humidity is required. It is usually too warm, however, for recirculation for low temperature and for low humidities, and must be cooled with cold water or its equivalent. High temperature together with high humidity requires an auxiliary hot water supply, which is hereinafter described, or else the use of the steam jets in conjunction with the sprays during the early stages of the run as described on page 30.

WATER MIXERS.

Each kiln is supplied with an automatic hot and cold water mixing valve, which mixes enough cold water with the recirculating water to deliver it to the sprays at the desired temperature.

During the first part of low-temperature runs the recirculating water may not be hot enough to hold the required humidity, and in this case it must be heated either by cracking the steam jet valve slightly so that the steam will raise the water to the desired temperature or by mixing in hot water.

SPRAY HEADS.

The spray heads consist of small brass nozzles connected by means of half bends of $\frac{1}{4}$-inch wrought-iron or brass pipe fitted into reducing tees on the supply pipe. The adjustable "vermorel" type of nozzle, such as is used in horticultural work, which will deliver 3.5 pounds of water per minute at 50 pounds pressure, has been found satisfactory. The nozzles have brass disks with .063-inch holes, which deliver a coarse spray, not a mist. They should be spaced from 18 to 20 inches apart in side spray-chambers, and from 12 to 14 inches in center spray chambers. The sprays must be lined up centrally with respect to the spray chamber, and must point directly downward.

QUANTITY OF WATER SUPPLY.

The amount of water delivered per unit of time and unit of kiln space is determined by the formula:

3.5 pounds per spray head multiplied by the number of heads per kiln= pounds of water delivered per minute.

or: $\frac{\text{Pounds of water}}{8\ 1/3}$=gallons per minute.

VELOCITY OF WATER IN PIPES.

The velocity of water in mains should not exceed 300 feet per minute, on account of the loss in pressure due to friction. In the smaller supply pipes the velocity should not exceed 180 feet per minute. The loss due to friction should not exceed $2\frac{1}{2}$ pounds per 100 linear feet of pipe. The proper velocity for a given amount of water can be determined from the chart on friction pressure losses. Find the number of gallons recirculated per minute on the left side of the chart and continue across this line until it intersects the line

above $2\frac{1}{2}$ pounds pressure loss. Interpolate for velocity between the two nearest diagonal lines marked "velocity in feet per second," and multiply by 60 to obtain velocity in feet per minute.

SIZE OF WATER PIPES.

Area of pipe in square feet times velocity of flow in feet per minute gives the delivery in cubic feet per minute. If the diameter is expressed in inches, the formula is as follows:

The diameter of pipe in inches

$$=4.95\sqrt{\frac{\text{Gal. per min.}}{\text{Velocity in feet per minute.}}} \qquad =14.29\sqrt{\frac{\text{lbs. per min.}}{\text{Velocity in feet per minute.}}}$$

For a velocity of 200 feet per minute, the diameter in inches

$$=0.35\sqrt{\text{gallons per minute}}=20.2\sqrt{\text{pounds per minute.}}$$

The size of supplies and mains can also be determined direct from the curves of friction pressure losses, by first determining or assuming the loss in pressure permissible per 100 feet of straight pipe.

LOSS OF PRESSURE IN PIPES.

The pressure loss due to friction may be determined from the chart in figure 10. It gives the loss of pressure in pounds per square inch per 100 feet length of standard sizes of pipe. In interpreting this chart it is convenient to note that for a given diameter gallons and cubic feet per minute are one and the same quantity merely expressed in different terms, and that for a given velocity of flow the quantity of water delivered varies as the square of the diameter.

A kiln 40 feet long having side spray chambers uses 20 gallons of water per minute. To find the size of supply between main and kiln, from 20 gallons on left of chart follow horizontally to intersection with the diagonal pipe size. One and one-half inch pipe gives a velocity of slightly over 3 feet per second or 200 feet per minute with pressure loss of 1.2 pounds, while the 2-inch pipe (by interpolation) gives a velocity of about 2 feet per second or 120 feet per minute with pressure loss of only 0.4 pound. Economy would suggest the use of the $1\frac{1}{2}$-inch pipe.

The branches from the supply pipe to the spray pipe use 10 gallons per minute. It can be seen from the curves that in 1-inch pipe the velocity would be nearly 4 feet per second or about 225 feet per minute, with a pressure loss of 2.5 pounds per 100 feet length; while in $1\frac{1}{4}$-inch pipe the velocity would be about 2 feet per second, or 120 feet per minute, with a pressure loss of only 0.7 pound. In this case the larger size would be better.

The size of all mains and branches should be so proportioned that the pressure loss will be equal on both cold and hot water mains between the pressure-regulating valves and the mixing valves.

For all bends, globe valves, or similar obstructions, consider the length of the pipe increased as follows: Right angle elbows, 40 diameters; tees, 45 diameters; globe valves, 60 diameters. Mixing valves will reduce the pressure from 2 to 5 pounds. For pipes having an equivalent pipe length over or under 100 feet, interpolate for the loss in pressure in proportion to the length.

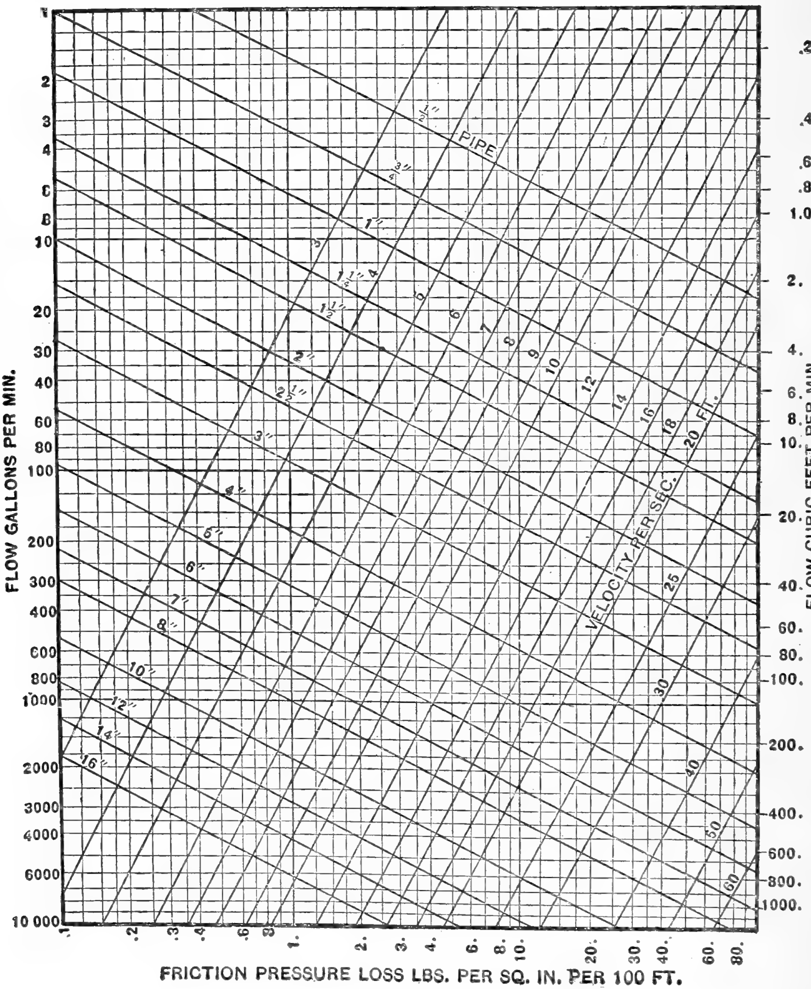


FIG. 10.

SIZE OF WATER MAINS.

The water main should be gradually increased in size as it approaches the source of supply in proportion to the amount of water required to supply the kilns. To determine the size at any given point, calculate the amount of water required in the kilns between that point and the end of the line away from the source of

supply. The amount of water to be used being known and a pressure loss between 1 pound and $2\frac{1}{2}$ pounds per 100 linear feet being assumed, the size can be obtained from figure 10.

In determining the size of mains to supply a given number of kiln units, first find the size of supply to each kiln by either method described. The diameter of the main then up to any given unit of a battery will be the diameter of the supply for one kiln multiplied by the square root of the number of kiln units between and including the given unit and the end farthest from the source of supply.

Where four kilns or less are installed, the mains should be proportioned as follows:

The cold-water main—full volume of water required in the kiln.
The recirculating main—full volume of water required in the kiln.
The hot-water main—two-thirds volume of water required in the kiln.

Where five or more kilns are installed the mains may be proportioned as follows:

The cold-water main—three-fourths volume of water required in kiln.
The recirculating main—full volume of water required in kiln.
The hot-water main—one-half volume of water required in kiln.

For the last four kilns in a battery, proportion the mains according to the first rule; mains supplying the last kiln should be full size.

The amount of cold water required to cool the recirculating water to the desired degree depends upon (1) the temperature of cold water in the warmest season of the year, and (2) the highest temperature and lowest humidity used in the kiln and the exposure of roof and side walls.

Low temperature runs require colder water through the sprays to obtain low humidities than do high temperature runs. A spray-water temperature of 65 to 70° F. is required to obtain a humidity of 33 to 38 per cent at 135° F.; while for a temperature of 180° and a humidity of 38 to 45 per cent the spray-water temperature must be from 120 to 135° F., only slightly below the temperature of the water as it flows into the recirculating well from the spray-chamber gutters. Thus the higher the temperature used, the less cold fresh water is required. For this reason, if the installation is to be used for low-temperature runs only, the sizes estimated above for mains should be changed to full size for cold-water main and three-fourths size for recirculating water main. If for high-temperature runs only, the hot-water main should be increased to three-fourths capacity, the recirculating main to full size, and the cold-water main to one-half size. Where only two mains are used, the recirculated and cold water, the recirculating main should be full size and the cold water three-fourth size for a battery of five or more kilns, and both full size for less than five kilns. It is always better to have the mains too large than too small.

PRESSURE REGULATION.

The water pressure must be nearly equal in each of the cold-water, recirculating-water, and hot-water mains, otherwise the mixing valves will be able to take water only from the main having the highest pressure. The difference must not exceed 5 pounds in pressure at any time. A steady pressure is necessary for uniforn temperature control; for if the pressure fluctuates more than 5 pounds satisfactory control is not obtainable.

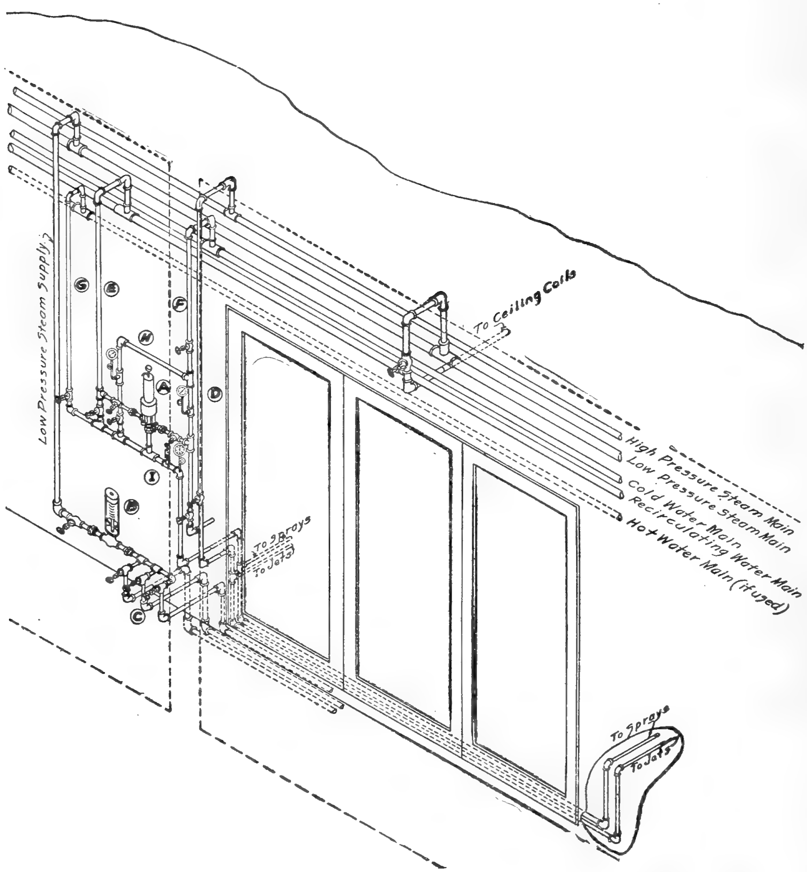


FIG. 11.—Diagram of steam and water supply connections and fittings. Overhead supply.

LEGEND.

A. Thermostatic water mixer.
B. Thermostat on steam supply to coils.
C. Supplies to coils.
D. Steam jet supply.
E. Recirculating water supply.
F. Cold-water supply.
G. Hot-water supply (when hot-water main is installed).
H. By-pass for cold-water past mixer.
I. Pipe thermometer for temperature of water to sprays.

The pressure in the recirculated and hot-water mains should be controlled by a pump regulator installed on the steam supply to the pump and connected on the pump side of the strainer. The cold-water-main pressure should be controlled by a pressure-regulating

valve capable of maintaining any water pressure desired between 40 and 60 pounds. In case the pressure in the cold-water main is less than 50 pounds an extra cold-water pump and well are required.

INSTALLATION OF WATER PIPING AND FITTINGS.

All piping should be genuine wrought iron of standard weight. Joints should be perfectly tight, iron to iron, without the use of red lead or cement.

Tees with plugged openings for water gauges should be installed on the kiln side of each water mixer and on the discharge of the pump beyond the strainer. (See fig. 11.)

The cold, recirculating, and hot-water mains should each be connected and properly valved to by-pass the water mixer separately.

An accurate water-pipe thermometer should be installed in the spray-line supply on the discharge side of the water mixer.

The spray-line pipe in the spray chamber should be in the middle and should be extended through the kiln wall at each end to a sill cock, in order that the system may be flushed out.

WATER MIXERS.

Each kiln should be provided with a thermostatic water mixer, installed between unions so that it may be removed for cleaning and inspection.

Some water mixers have a temperature range of only 60 degrees, others as high as 100 degrees. The upper limit of the temperature range of a mixer should be at least 20 degrees higher than the lowest initial temperature of the drying schedule to be used in the kilns.

Water mixers are entirely self contained, requiring no outside agency such as air or electricity to operate them.

Inlets and discharge should be full size of spray-line supply.

WELLS.

RECIRCULATING WELL.

The well should be capable of holding a supply of water for 10 minutes and the required capacity may be determined as follows:

$$\frac{\text{Pounds per kiln per minute} \times \text{number of kilns} \times 10}{62\frac{1}{2}}$$

= cubic feet required in well below water line.

The hot well, where used, should be about one-third the size of the recirculating well. When the hot well is dispensed with, a steam pipe should be installed for heating the water in the well when required.

The general shape of a well depends upon local conditions affecting the installation, such as nature of soil, drainage system, etc. The well should be constructed of concrete, waterproofed with a reliable integral waterproofing.

An overflow to sewer of capacity of the return water drain should be placed near the inflow. A steam syphon or pump in place of natural drainage to sewer should not be used. Some means should be provided for emptying the well for cleaning, either by a valved drain when the bottom of the well is above the sewer, or by a steam syphon or pump.

A cold-water supply should be brought to the well and connected through a float valve to supply any deficiency and to maintain the constant water level at all times.

HOT WELL.

In some installations two wells are used: One for recirculating water and one for hot water. A hot well is needed where high temperature runs are to be made. In such cases the returning spray water is not hot enough to maintain the desired humidity.

Where the need of hot water would only occur occasionally—that is, where high temperature runs are the exception rather than the rule—is is undoubtedly more economical to use the steam jet as indicated under "Water supply" to raise the temperature of the water at the sprays to the desired temperature than to resort to the use of the hot well. Two wells are advisable, however, where a wide range of temperature is to be used on green stock.

Where hot wells are used, three water mains are necessary—hot, tempered, and cold—and all are cross-connected at the water mixer.

The temperature of the water in the hot well can be controlled thermostatically, where necessary, by installing a self-controlled or air-controlled thermostatic valve, having the control bulb in the well and the valve on a high pressure steam supply opening into the well.

Where convenient the full or partial condensation from the coils may be turned into the hot well after passing through an oil strainer.

HOT WATER TANK.

Another method of supplying the necessary hot water is to take a branch off the recirculating main to a closed steel tank where it is heated by heating coils. From the tank the hot water is carried to the kiln by a hot-water main, as described heretofore. This does away with the need of a hot-water pump, as the recirculating pump furnishes the pressure for both recirculating and hot-water supplies.

The tank should have a capacity of from one-fourth to one-third that of the recirculating well, depending upon the amount of hot water needed.

The heating coils in the tank must be supplied with high pressure steam to raise the temperature of the water to 185 or 190 degrees.

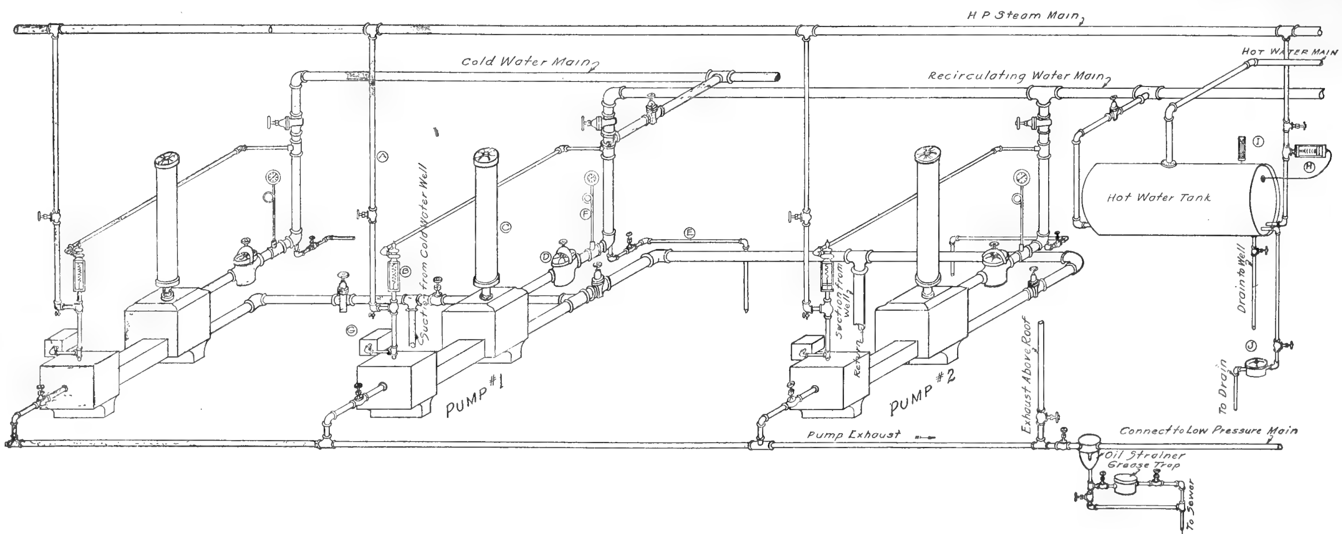


FIG. 12.—Duplicate pumps for recirculating water. Either one can be used while the other is shut down for repairs or cleaning. Hot-water tank not necessary in low-temperature runs.

LEGEND.

A. H. P. steam supply to pump.
B. Pump governor.
C. Air chamber.
D. Strainer in discharge.
E. Relief and drain pipe.
F. Pressure gauge.
G. Force feed oiler.
H. Thermostat controlling tank temperature.
I. Pipe thermometer.
J. Steam trap.

The temperature of the water can be controlled automatically by a thermostatic tank regulator, having the control bulb in the tank and the valve on the steam supply to the coils therein.

The use of the tank in place of a hot well has many features which recommend it in many installations. Of first importance among these is the elimination of the hot water pump. When the temperature of the water is within 20 or 30 degrees of the boiling point it becomes very difficult to pump and causes more or less trouble with the pump packing, etc. The use of the tank obviates this difficulty. One method of connecting the tank to the recirculating main is shown on figure 12.

SIMPLIFIED HUMIDITY CONTROL.

It is evident that the humidity may be changed by changing the kiln temperature, by changing the water temperature, or by both. Where more than one temperature schedule is used simultaneously in different kilns of a battery, the desired schedules are obtained by changing both the kiln and water temperatures during the progress of the run. Where only one low temperature high humidity drying schedule is used in the entire battery, such as would be required for slow drying heavy oak stock, the desired schedule may be obtained by maintaining the temperature of the spray water constant at one temperature throughout the run and in all kilns in the battery. In this case the humidity is lowered during the progress of the run by raising the kiln temperature. Where this method may be used only one well, one pump, and one water main are required and the mixing valves are not necessary. The water temperature is kept constant in the well by allowing more or less fresh cold water to flow into it, the amount depending upon the difference between the temperature of the returning spray water and the desired temperature of the water in the well. The proper method of piping connection for this type of installation is illustrated in figure 9. Figure 13 shows a simple method of installing the pump, including live steam jet line in well to raise the temperature of the water and cold water line to lower the well temperature.

FILTERS.

The recirculating water is very apt to contain dirt, sediment, or a stringy vegetable growth, which causes much trouble if it gets into the spray heads. This foreign matter should be intercepted by installing a filter in the well between the return drain and the pump intake. Such a filter can be built of burlap stretched over wooden frames. The frames are made to slide in wood jambs on the sides of the well and may be easily taken out for cleaning and repairing.

The return water from the spray chamber gutters should pass through three screens before reaching the pump intake. Several

extra screens should be provided in order that a clean screen may be slipped in when a dirty screen is taken out. The dirty screens may be cleaned by washing with a hose on the reverse side. The frames

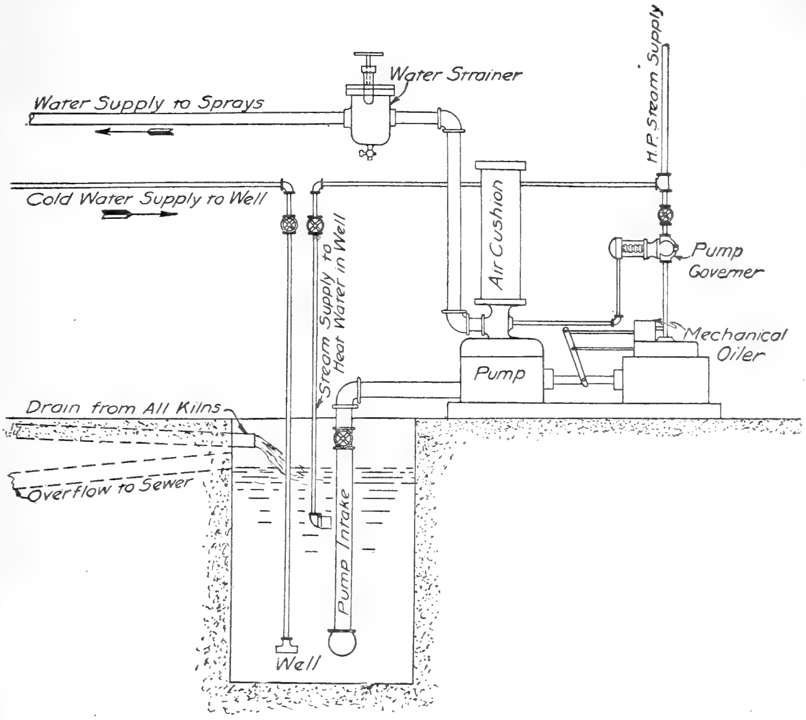


FIG. 13.—Pump connections for simplified humidity control for use in kilns where only one drying schedule will be used. (See page 40.)

and jambs should be built of cypress and fastened together with brass screws. The burlap should be attached to frames with separate strips held in place by screws.

GUTTER.

The gutter at the bottom of the spray chamber should have a pitch to the drain of at least 1 inch in 8 feet, and should be not less than 3 inches deep at the shallow end. It should connect with the drain pipe through a cast iron wash rack without trap.

DRAIN PIPE.

Wherever practical, drain piping should be cast iron soil pipe with regular oakum and lead calked joints, graded to the return well with a pitch of 1 inch in 10 feet.

The drain pipe should have a by-pass to the sewer for flushing out débris in piping before starting kilns. For less expensive installation sewer tile can be used.

TABLE 8.—*Capacity of drain pipe of various sizes based on a slope of 1 inch in 10 feet.*

Gallons per minute.	Required diameter in inches.
50	4
75	5
100	6
150	7
200	8

Increasing the slope increases the capacity. The graduation of drain pipe sizes to accommodate drainage from a battery of kilns may be figured according to general suggestions under "Size of mains."

PUMPS.

The pump found to be most suitable for dry-kiln work is the direct-acting boiler-feed type, duplex-piston pattern, bronze or brass fitted with brass-lined cylinder, water pistons submerged, and composition valves. The piston should be packed with a high grade hot water packing.

Pumps should be set in accordance with manufacturer's instructions and the hot well pump should be below the level of the water in the hot well to obviate loss of priming. No reductions should be made in the size of the inlet or outlet connections. Sufficient working space should be allowed around the pump to permit the operator to oil and overhaul it without danger while it is in motion.

The suction pipe should be as short and direct as possible and fitted with a foot valve and box strainer at the intake.

Each pump should be equipped with a pump governor to regulate the discharge of water from the pump in accordance with the demand of the water mixer, the pressure in this way being kept balanced with that in the cold water main held by the pressure-regulating valve. A pressure gauge of the Bourdon type should be placed on the discharge, in a convenient place for observation.

The discharge from each pump should be equipped with a self-cleaning strainer of the pot type, the full size of the discharge pipe and designed to withstand full pressure. Such a strainer should be provided with a drip connection to sewer, properly valved so that dirt and sediment can be removed from time to time. A by-pass and valves around strainer should be provided in order that the strainer may be removed for repairs if necessary without shutting down the kilns.

The pumps should be equipped with a sight-feed mechanically forced oil lubricator.

If the exhaust steam from the pumps is to be used in the heating coils the exhaust from all pumps should unite into a common exhaust main discharge, through an oil separator, and into the low

pressure steam main. The oil separator should drip through a grease trap, be valved, and discharge into the sewer.

Provide a vent pipe for the exhaust main to discharge to the atmosphere through a back-pressure valve.

AIR CHAMBERS.

The discharge from the pump being intermittent, each successive impulse is equivalent to a blow affecting not only the pump but the whole system. An air cushion is obtained by installing an air cushion chamber, which gives a smooth-flowing and continuous delivery to the mains. The air chamber should be on the highest portion of the pump and directly over the highest part of the delivery opening.

The air chamber usually furnished with the pump should be removed and an 8-inch wrought-iron pipe long enough to have double the capacity of the ordinary air chamber should be substituted therefor.

The supply of air in the air chamber gradually disappears while the pump is in motion and requires occasional draining unless some method is provided of keeping the air supply constant. One such method is to place a pet cock on the pump intake on the intake side of the check valve. This pet cock should be on a short nipple and open to the atmosphere. Cracking the pet cock will provide for drawing in enough air at each impulse of the pump to keep the air chamber charged.

PUMP SIZES.

The amount of recirculated water can be determined according to the method used in obtaining the size of mains (see "Water Supply"); then

Gallons of water recirculated per kiln $\times$ number of kilns = maximum capacity of pump in gallons.

The pump should be built to withstand a constant working pressure of not less than 100 pounds. It is advisable that all pumps of an installation be of the same size because this permits the interchange of spare parts, facilitates repairs, and makes it possible to use any pump on any main in case of a breakdown of the pump regularly supplying that main.

One pump in excess of the actual number required should be installed whenever possible as it may prevent shutting down the kilns while pumps are being repaired.

All pumps should be cross connected to all mains through properly valved branches.

The pumps should be capable of supplying the total amount of water recirculated per minute at a piston speed of between 30 and 40 feet per minute.

The following table of pump capacities, speeds, steam supplies, exhausts, etc., is based on the standards used by a well-known manufacturer of pumps.

TABLE 9.—*Standard sizes of pumps.*

Diameter of steam-cylinders.	Diameter of water plunger.	Length of stroke.	Displacement per stroke of one plunger.	Proper strokes per minute of one plunger, varying with kind of work and pressure.	Gallons delivered per minute by both plungers at stated number of strokes.	Diameter of plunger required in any single cylinder pump to do the same work at same speed.	Diameter of pipes for short lengths—to be increased as length increases.			
							Steam pipe.	Exhaust pipe.	Suction pipe.	Discharge pipe.
Inches.	*Inches.*	*Inches.*	*Gallons.*	*Number.*	*Gallons.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
3	2	3	0.04	100 to 250	8 to 20	$2\frac{7}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$1\frac{1}{4}$	1
$4\frac{1}{2}$	$2\frac{3}{4}$	4	.10	100 to 200	20 to 40	4	$\frac{1}{2}$	$\frac{3}{4}$	2	$1\frac{1}{2}$
$5\frac{1}{4}$	$3\frac{1}{2}$	5	.20	100 to 200	40 to 80	5	$\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$
6	4	6	.33	100 to 150	70 to 100	$5\frac{5}{8}$	1	$1\frac{1}{2}$	3	2
$7\frac{1}{2}$	$4\frac{1}{2}$	6	.42	100 to 150	85 to 125	$6\frac{3}{8}$	$1\frac{1}{2}$	2	4	3
$7\frac{1}{2}$	5	6	.51	100 to 150	100 to 150	7	$1\frac{1}{2}$	2	4	3
$7\frac{1}{2}$	$4\frac{1}{2}$	10	.69	75 to 125	100 to 170	$6\frac{3}{8}$	$1\frac{1}{2}$	2	4	3
9	$5\frac{1}{4}$	10	.93	75 to 125	135 to 230	$7\frac{1}{2}$	2	$2\frac{1}{2}$	4	3
10	6	10	1.22	75 to 125	180 to 300	$8\frac{1}{2}$	2	$2\frac{1}{2}$	5	4
10	7	10	1.66	75 to 125	245 to 410	$9\frac{7}{8}$	2	$2\frac{1}{2}$	6	5
12	7	10	1.66	75 to 125	245 to 410	$9\frac{7}{8}$	$2\frac{1}{2}$	3	6	5
14	7	10	1.66	75 to 125	245 to 410	$9\frac{7}{8}$	$2\frac{1}{2}$	3	6	5
12	$8\frac{1}{2}$	10	2.45	75 to 125	365 to 610	12	$2\frac{1}{2}$	3	6	5
14	$8\frac{1}{2}$	10	2.45	75 to 125	365 to 610	12	$2\frac{1}{2}$	3	6	5
16	$8\frac{1}{2}$	10	2.45	75 to 125	365 to 610	12	$2\frac{1}{2}$	3	6	5
$18\frac{1}{2}$	$8\frac{1}{2}$	10	2.45	75 to 125	365 to 610	12	3	$3\frac{1}{2}$	6	5
20	$8\frac{1}{2}$	10	2.45	75 to 125	365 to 610	12	4	5	6	5
12	$10\frac{1}{4}$	10	3.57	75 to 125	530 to 890	$14\frac{1}{4}$	$2\frac{1}{2}$	3	8	7
14	$10\frac{1}{4}$	10	3.57	75 to 125	530 to 890	$14\frac{1}{4}$	$2\frac{1}{2}$	3	8	7
16	$10\frac{1}{4}$	10	3.57	75 to 125	530 to 890	$14\frac{1}{4}$	$2\frac{1}{2}$	3	8	7
$18\frac{1}{2}$	$10\frac{1}{4}$	10	3.57	75 to 125	530 to 890	$14\frac{1}{4}$	3	$3\frac{1}{2}$	8	7
20	$10\frac{1}{4}$	10	3.57	75 to 125	530 to 890	$14\frac{1}{4}$	4	5	8	7
14	12	10	4.89	75 to 125	730 to 1,200	17	$\frac{1}{2}$	3	10	8

CONDENSER COIL.

The condensing coils are placed in or near the spray chamber in the leaving-air flue and are used at the end of a kiln run when high circulation and high humidity are not needed. They work on the same condensing principle as the sprays, cooling a portion of the leaving air to the dew-point temperature, thus condensing the moisture evaporated from the lumber.

When condensers are in use the circulation of air in the kiln is produced by the difference in pressure due to the difference in temperature between the heated air in the entering-air flue and the cooler air in the spray chamber. A circulation produced by this method is very feeble at 50 per cent humidity and practically disappears at 75 per cent humidity. While the use of condenser coils is more or less satisfactory for low humidities, particularly in long runs, the drying time is extended somewhat. The humidity in the kiln under such circumstances is controlled by regulating the amount of cold water admitted to the coil through the supply valve.

To estimate the approximate amount of coil surface required, 1 square foot of coil should be allowed for every 20 cubic feet of kiln space above the rails. If cold water is available throughout the year, less coil is needed. Where the temperature of the water is not over 50° F. in the hottest weather of the season the coil area can be reduced 25 per cent.

The condenser coil can be built up of 1-inch or 1¼-inch pipe connected with cast-iron return bends and supported by hook plates.

The supply is taken from the cold-water main through a gate valve to the bottom of the coil. The discharge is taken from the top of the coil and should be extended well down into the spray chamber, where it empties into the gutter.

CONTROL INSTRUMENTS.

REQUIRED DETERMINATIONS.

The temperature and humidity in the water spray kiln are determined from two thermometer readings, one taken in the entering-air flue and the other in the baffle plates. The baffle plate thermometer gives the dew-point temperature. This thermometer should be placed in the lower opening of one of the boxes on the spray chamber side but in such a manner that it does not receive a direct spray of water nor rest on the floor of the kiln.

The entering-air temperatures should be taken about halfway to the top of the pile and in the center of the flue.

RECORDING THERMOMETERS.

Four types of extension-tube recording thermometers are made, their principal differences depending upon whether the element contained in the bulb is (1) mercury, (2) nonvolatile liquid, (3) gas, or (4) a volatile liquid (called vapor-filled).

For dry-kiln work the gas-filled and vapor-filled thermometers are found most desirable.

The vapor-filled type is more rapid in action than the gas type and gives good satisfaction provided it can be installed so that no portion of the tube or case is at a higher temperature than the bulb itself. This is very difficult to do, particularly with the dew-point bulb, as some portion of the tube frequently has to pass near a steam pipe or through a space warmer than the baffles. Adjustment must be made for vertical distance between the bulb and the recording spring, due to the liquid head in the tube. A recent type of vapor-filled thermometer has been made with a large bulb, in which it is alleged that the temperature of the tube and case do not affect the reading. The vapor-filled type is more accurate than the other forms, because changes in the volume of the spring bulb or tube do not affect its operation, as it acts simply on the principle of a steam-pressure gauge.

The gas-filled type is more sluggish in action than the vapor type, but gives the temperature of the bulb only, not being affected by higher or lower temperatures along the tube or at the dial.

The gas-filled thermometers are not affected by the height of the bulb so that it is possible to remove the bulbs from the kiln for calibration in water. The vapor-filled thermometers must be calibrated in place.

Recording instruments have not proved altogether reliable and should not be wholly depended upon. They should be regularly compared with a standard glass thermometer. Recorders are very valuable, however, in indicating whether kiln conditions are steady, variable, rising, or falling, making it possible for the operator to regulate the kiln from the operating room with a great saving of time. Recorders may be obtained in single-pen or double-pen cases, 24-hour or 7-day charts, with 8-inch or 12-inch dials. There is no object in procuring recording thermometers with a very wide temperature range. In fact, if a chart is selected which will record temperature about 20 degrees higher and lower than the highest and lowest temperature to be used, the divisions on the chart will be wide and easy to read accurately. Fifteen feet of flexible tubing is enough in most kilns.

SOME POINTS TO BE EMPHASIZED IN SPECIFICATIONS.

Gravel, dirt, filings, oil, or other foreign matter in the steam and water piping is responsible for much of the trouble experienced when starting a battery of new kilns and causes loss of time and expense until the system is made clean. Such trouble and expense can be reduced, if not entirely eliminated, by careful handling of piping and fittings from the time they are delivered until installed. The designer therefore should take pains to emphasize in the specifications the precautions to be taken, and the superintendent should see that these precautions are carried out.

When pipe is being delivered have it piled at delivery on blocks or supports free of the ground or floor. Fittings should be kept in the gunnysacks in which they are delivered and not permitted to be kicked around.

Both ends of the pipe should be reamed after threading. Before assembling, each pipe is to be stood on end and pounded with a hammer to remove any scale or dirt. Fittings must be perfectly tight, iron to iron, without the use of red lead or cement.

The water mains should be thoroughly flushed out, with full head of hot water, before supplies are attached to kiln. Next, the supplies to kilns and spray lines should be similarly flushed before water mixers or spray nozzles are installed.

All pipe used inside the kilns should be genuine wrought iron, not steel, and should not be galvanized.

All exposed runs of piping should be covered with a suitable air-cell pipe covering. The cold-water main should be covered with a moisture-proof pipe covering

All controlling valves should be angle or gate valves except in special cases. Where globe valves are used they should be set with the stem horizontal, to avoid water or steam pockets.

TABLE 10.—*Standard wrought-iron pipe.*

[Hoffman's Handbook for heating and ventilating engineers.]

Trade size.	External size.	Internal size.	Internal area.	Length of pipe per 1 square foot of area.	Length of pipe containing 1 cubic foot.	Surface per linear foot of pipe.	Nominal weight per foot.	Weight of water per linear foot.
Inches.	*Inches.*	*Inches.*	*Sq. in.*	*Feet.*	*Feet.*	*Sq. feet.*	*Pounds.*	*Pounds.*
¾	1.050	.824	.5333	3.637	270.0	.275	1.115	.230
1	1.315	1.048	.8609	2.904	166.9	.346	1.668	.373
1¼	1.660	1.380	1.496	2.301	96.25	.434	2.244	.648
1½	1.900	1.611	2.038	2.010	70.66	.494	2.678	.883
2	2.375	2.067	3.356	1.608	42.91	.622	3.609	1.454
2½	2.875	2.468	4.780	1.328	30.10	.753	5.739	2.072
3	3.500	3.067	7.388	1.091	19.50	.916	7.536	3.202
4	4.500	4.026	12.730	.849	11.31	1.175	10.665	5.517
5	5.563	5.045	19.985	.687	7.20	1.455	14.502	8.668
6	6.625	6.065	28.886	.577	4.98	1.739	18.762	12.521
7	7.625	7.023	38.743	.501	3.72	1.996	23.271	16.790
8	8.625	7.982	50.021	.443	2.88	2.257	28.177	21.683

TABLE 11.—*Water conversion factors.*[1]

United States gallons	×	8.33	=pounds.
United States gallons	×	0.13368	=cubic feet.
United States gallons	×	231.00000	=cubic inches.
Cubic inches of water (39.1°)	×	0.036024	=pounds.
Cubic inches of water (39.1°)	×	0.004329	=United States gallons.
Cubic feet of water (39.1°)	×	62.425	=pounds.
Cubic feet of water (39.1°)	×	7.48	=United States gallons.
Cubic feet of water (39.1°)	×	0.028	=tons.
Pounds of water	×	27.72	=cubic inches.
Pounds of water	×	0.01602	=cubic feet.
Pounds of water	×	0.12	=United States gallons.

[1] American Machinist Handbook.

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